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BRITISH PROGRESS IN MUNICIPAL ENGINEERING

NATIONAL ENGINEERING AND TRADE LECTURES

ASSISTED BY THE BOARD OF TRADE, COLONIAL AND FOREIGN
OFFICES, COLONIAL AND FOREIGN GOVERNMENTS AND LEADING
TECHNICAL AND TRADE INSTITUTIONS

EDITED BY BEN H. MORGAN

VOLUME I

British Progress in Municipal Engineering

A Series of Three Lectures

BY

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British Association of Waterworks Engineers; Member of Association
of Municipal and County Engineers;
Author of "Refuse Destructors" "Construction of Roads and Streets" etc.
President of the Institute of Sanitary Engineers, London.

1. GENERAL—ROAD ENGINEERING AND MAINTENANCE
2. MAIN DRAINAGE, SEWAGE DISPOSAL, DESTRUCTORS
3. WATER SUPPLY—CONCLUSION

WITH NUMEROUS ILLUSTRATIONS AND THREE CLASSIFIED LISTS OF BRITISH MANUFACTURERS OF MUNICIPAL ENGINEERING PLANT AND MATERIAL

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LECTURE I

GENERAL—ROAD ENGINEERING AND MAINTENANCE

Introduction

UPON acceding to the request that I should deal with the subject of "British Progress in Municipal Engineering" in connexion with the present important scheme of National Engineering and Trade Lectures, at the outset I realized the necessity of marking out, somewhat more definitely than is generally understood by the use of the term "Municipal Engineering," the field to be reviewed within the compass of the present address.

As applied in Great Britain, this phrase may be taken to include every class of constructional work or local public service that may be required to meet the common needs of any populated centre in a manner commensurate with the highest standards of excellence dictated largely by the state of social progress then prevailing. So comprehensive a definition would, however, obviously embark us upon an inquiry too extensive for the purposes of the present case, as its ramifications would necessarily encroach very largely upon the whole scope of the practice of the Civil, Electrical, Hydraulic and Mechanical Engineer, as well as upon that of the Architect and the Surveyor, including in each case their several subsidiary branches. I propose, therefore, to limit myself to a review of the progress made in those departments of municipal activity which it is unquestionably the function of a Public Authority, acting under certain statutory powers and obligations, to carry out, and omitting those branches which by many are considered (whether rightly or wrongly is not our present purpose to determine) to fall within the category of "Municipal Trading."

These primary duties may be taken to include the construction and maintenance in the best possible manner of all Roadways, Footways and Pavements, the Scavenging, cleansing and watering of streets, and the construction and maintenance of an adequate system of Main Drainage and Sewer Ventilation, perfected and completed only by equally sound and effective systems of House Sanitation. There is also the important duty of the prompt and systematic removal of all wastes from amongst a population, including the Treatment and Disposal of Sewage and the Collection and Disposal of House and Trade Refuse in such a manner as will ensure the highest degree of protection to the public health. This latter duty embraces the erection of Refuse Destructors and the turning to account of the calorific value of refuse for the production of steam for various municipal purposes.

To the foregoing must be added the Lighting, Widening and Improvement of Streets, the rebuilding of overcrowded areas, the provision of Public Conveniences, Abattoirs, Markets, Mortuaries, and Baths, and the laying out of Parks, Pleasure Grounds and other ornamental works. In many towns works of Marine and River Engineering also have special prominence owing to local conditions, and these involve the Construction of Tidal and Sea-defence Works, the diversion, improvement, and bridging of rivers, and the Prevention of Floods. There is, too, the crowning duty of the provision of a pure and adequate Water Supply, a question more directly affecting the public health than any that could fall to the lot of a Public Authority to carry out.

These, then, are the principal branches of municipal work under which are to be observed the advances that have been made and the manner in which the demands of progress have been met by the combined efforts of the State, the Public Authorities, Engineers and Manufacturers of Great Britain.

Municipal progress is largely coincident with the social progress of the people and the developments of science. Periods of stagnation in the history of nations are invariably punctuated with the evils attendant upon sanitary and hygienic retrogression as illustrated in the case of the English nation by the plagues and epidemics which visited our shores during the Middle Ages. Until 1531 no provision was made in London for the construction of underground main sewers, at which date a "Commission" was appointed under an Act of Henry III, and even down to the year 1848, the date of the first Public Health Act, the discharge of house sewage into the main-drainage was forbidden and the construction of cesspools enforced! Public Sanitation was practically unknown a hundred years ago, and no real progress seems to have been made until about the middle of the nineteenth century, during the life of the great and good Queen whose reign has so recently passed into the domain of history. From this time onwards rapid and mighty strides have been made in the development of Sanitary Science, and in the propress of Municipal Engineering, thus leading up to the high standards of excellence which obtain throughout Great Britain.

The discoveries of the Victorian era, an era which has been fruitful to a remarkable degree, have permeated, changed, and advanced every department of life in a manner wholly without parallel in the history of any nation. Scientific research was never more active, profound, and far-reaching, neither has the practical application of the discoveries of any period so completely revolutionized the conditions of everyday life.

The great mass of the people of Great Britain down to the accession of Queen Victoria, lived, worked, and died under conditions which grossly violated the now well-known principles or laws of health, and the progress of hygiene, such as it was, entirely rested for many ages upon an empirical basis. Earlier progress was hindered by ignorance, prejudice, Government indifference, and internal strife and unrest. The people knew but little, and thought less, of the importance of pure water, food, and air, of the necessity for healthy, cleanly dwellings and other such conditions which we now rightly regard as first essentials to health. In the earlier stages of sanitary reform much is to be attributed to the efforts of such pioneers as Chadwick, Neil Arnott, Simon, Parkes, Corfield, Buchanan, Galton, Rawlinson, Rogers Field, and others, who laboured successfully in the application of the teachings of science to practical sanitary work. The Government Inquiry into the health of towns begun by Chadwick some fifty years ago, led to the appointment of Medical Officers of Health to the different towns, and has done much to diffuse a knowledge of hygiene among the people.

Statesmen, too, have now learnt that it is the duty of executive governments to safely guard the public health, and that Sanitary Science is an element in practical politics which must not be overlooked. A cursory survey of the period since 1848 will show that a large mass of legislation has from time to time been brought into existence dealing exhaustively with the details of Sanitary Administration, safeguarding the public health to a degree never before contemplated, and largely improving the social condition of the masses. This period is more especially punctuated by such statutes as the Public Health Act, 1875, and the Public Health (London) Act, 1891, and the general trend of all such legislation has decidedly been towards securing a higher standard of sanitation in the dwelling-house, the factory and workshop, and other inhabited places, as well as making suitable provision for the public requirements in all matters of main-drainage, sewage disposal, water supply, public street improvements, and such like.

The practical result of these important changes has been a marked improvement in vital statistics, as evidenced by the greatly reduced death-rate and enhanced expectation of life. Some potential causes of death have very materially declined, whilst others have become almost wholly extinct. Two centuries ago the mortality of London was put as high as 80 per 1,000, whilst to-day it is less than one-fourth of that rate. The effects of great wars and political earthquakes become wholly eclipsed in comparison with the lasting national benefits resulting from these silent social changes.

There is, however, no finality in *progress*, and much doubtless still remains to be done in all departments of this wide sphere. The spirit of original research is more active and fruitful to-day than at any previous date, and much scientific work of sterling worth is being carried out by many of our large cities and towns in connexion with investigations into the profitable use of waste materials, the bacteriological treatment of sewage, the biology of sand filtration of water supplies, and other important branches of municipal work.

Thus, by a rapid succession of advances, confined practically to the past half-century, has the whole programme of municipal engineering practice as we now know it been speedily built up. Oftentimes theories initiated in the laboratory, but pooh-poohed by the man in the street, have, upon maturer investigation, become the accepted practice of to-day. At the same time the test of experience has doomed many fancied discoveries and valueless "inventions" to the eternal oblivion they so richly deserved.

All along the line of progress the British manufacturer has been fully alive to the changes taking place around him, and he has spared no pains to promptly place upon the market, at the opportune moment, the article required to meet each step of advance, as it were, day by day. To the design of these he has invariably applied the latest teachings of science, deduced oftentimes from his own protracted and costly experiments, thus leading the world of *Supply* and stimulating that of *Demand*. In all departments he has surrounded us with productions of their several kinds unsurpassed in quality and design, and to him much credit is undoubtedly due. His efforts are constantly being called upon to devise and supply a great diversity of apparatus and plant required in connexion with the plans and schemes of engineering experts whose duty it may be to design and carry out the various classes of public works such as I have already indicated.

Some idea of the magnitude of the operations of our large municipalities at the present day may be gained from a consideration of a few of the leading figures connected with the work of the *London County Council*—the largest municipality in the world. The scale of operations amongst the other authorities, though less in magnitude, is of a similar character, being, as a rule, more or less proportionate to the area and population served.

The ancient City of London and the surrounding area of the County of London together constitute *modern* London—the capital of the British Empire and the seat of the Imperial Government. The Administrative County of London is 74,839·4 acres in extent, has a population of 4,536,541[1] and a rateable value[2] of £37,492,502. The representative governing authority of this large area is the "London County Council," which body was con-

[1] Census Report, 1901.

[2] March 31, 1901.

stituted fifteen years ago by the Local Government Act of 1888. The Council exercises administrative functions incidental to the government of both counties and municipal boroughs, and also performs many special London services, and has certain powers of supervision and of acting in default of the local authorities within its area in certain matters. To carry out the vast programme of duties coming within the scope of this authority entails the employment of the largest municipal staff in the world. The number of officials at the central offices is between 800 and 900, and the total number of persons of all classes, including both those on yearly salaries and weekly wages in the employment of the Council for the year ended March 31, 1901, was 12,655, costing a total of £1,068,000 in salaries and wages. The total rent paid or estimated in respect of office accommodation at the end of the year 1900–1 amounted to £15,460 per annum, and the actual total of the Council's printing bill for the year ended March 31, 1902, was no less than £11,111.

The maintenance of the main drainage and the treatment and disposal of the sewage of so large a community alone necessitates the employment of a permanent staff of 930 men. In addition to the Administrative County of London some of the neighbouring non-county districts drain into the London main sewers under special powers conferred by Parliament, and the total area served by the Metropolitan main drainage system is 140½ square miles in extent, with a population of 5,137,435.[1] The year's volume of sewage is over 85,595 million gallons, equal to an average flow of 234½ million gallons a day. The treatment of this large volume at the Barking and Crossness Outfalls involves during the year the use of 21,645 tons of lime, and 5,428 tons of proto-sulphate of iron, and the precipitated "sludge," amounting to nearly 48,000 tons per week, is carried out to sea to the Barrow Deep in six sludge vessels owned by the Council. The engines of these vessels indicate 1,000 H.P. each, and each vessel carries a load of about 1,000 tons.

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[1] Annual Report L.C.C. for year ending March 31, 1902.

The total length of intercepting, outfall, main and storm-relief sewers under the Council's charge is 288 miles, and the net maintenance expenditure on the main drainage system for the year ended March, 1902, including the treatment at the outfalls, pumping stations, sludge vessels, cleansing and general expenses to the sewers, was £246,694, equal to a rate of 1·63*d.* in the £. The total net capital cost of the system from January 1, 1856, to March 31, 1902, has been £8,386,490. The sewage north of the Thames reaches the Barking Works through three nine-feet barrel sewers collectively termed the northern outfall sewer, whilst that on the south of the river flows to Crossness through the southern outfall sewer 11′ 6″ in diameter. Both these outfalls of late years have become very inadequate, and it is proposed to construct additional sewers of about the same capacity. As a popular summary of the work of the treatment and disposal of London's sewage, it may be stated that the flow of sewage during the year 1902 represents a canal 24 feet wide, with a depth of about 9 feet, running day and night at the rate of 2 feet per second, or is equivalent to a lake of 44 square miles in area and 11·2 feet deep. The quantity of sludge sent to sea would cover Hyde Park, an area of 400 acres, to a depth of about 5¼ feet, and the fleet of six sludge steamers travelled a total distance during the year of 260,600 miles, representing a journey of nearly 10½ times round the earth.

An examination of the leading features of the many other branches of the Council's work are equally striking in their magnitude. Our attention, for example, is arrested by the fact of 'the rapid growth which takes place year by year in the aggregate of the Council's financial transactions. Last year the amount of money which passed into and out of the coffers of the London County Council reached the sum of £10,058,471, or more than the expenditure of many a European State. The corresponding figure for the first year of the Council's existence was £3,303,923, so that there has been an increase of over 200 per cent. in the aggregate moneys dealt with.

If we examine the internal municipal life of any of the large provincial towns in Great Britain we find the same characteristic features, indicating the greatest municipal activity upon a highly organized system embracing all departments of local public service.

Two centuries ago the population of *Liverpool* did not exceed 5,700 persons. By the year 1801 the maritime and commercial progress of the port had increased this to a population of 77,000 persons, and to no less than 720,000 persons in the present year (1904). The city boundaries now include an area of 14,909 acres, and the continual development of this thriving city has afforded the greatest scope for substantial progress in all branches of municipal engineering.

The works necessary for the maintenance of the public health and the efficient sanitary administration of the city and port of Liverpool—open as it is to traffic from all parts of the world—are of primary importance, and are constantly receiving the fullest and unremitting vigilance of the civic fathers.

The present staff of the Medical Officer of Health consists of nearly 150 Inspectors engaged in the various branches of sanitary administrative work. In 1848, upon the Report of the then Borough Engineer, a thorough scheme of sewerage and drainage for the town was initiated, and which has long since been effectually carried on until the whole of the sewers have been put into a thoroughly sound condition and properly ventilated. This of itself has been a great work, seeing that the city contains 820 miles of sewers, comprising 78 miles of main outfalls, 416 miles of brick and pipe sewers, and 326 miles of passage sewers. Further, in the interests of the health of the town the Corporation not only flushes its own sewers where required, but the private drains are also flushed periodically twice a year, at a cost of about £4,500 per annum, and any additional special flushing necessary is done on payment of a nominal charge.

Coming to the question of the collection and disposal of refuse in this city, the Corporation of Liverpool have, since the year 1867, carried out with their own staff the whole of the scavenging and cleansing operations of the city, and have erected large stables and workshops and maintain a large stud of horses in each of the stables. The quantity of refuse dealt with annually amounts to about 350,000 tons, consisting of ashes, street sweepings, abattoir offal, etc., and in the removal of this material 180 horses are constantly employed. Motor dust wagons have also been introduced for the collection of the refuse: each wagon is capable of carrying a load of four tons, and of running daily an average of twenty-four miles. The motors have also been employed for street watering, gravelling, etc. To dispose of the vast quantity of refuse daily produced by the city, the Corporation have adopted two principal methods: (1) The conveying of a portion of the refuse to sea, and (2) the burning and reduction of the material in refuse destructors. Two steam hopper barges, the *Alpha* (built 1880), and the *Beta* (built 1884), carry loads of about 330 and 400 tons of refuse respectively to a point outside the bar of the river Mersey, twenty-three miles distant from the Liverpool landing stage. The principal mode of disposal, however, at the present time is by means of six destructor stations in different parts of the city, comprising an aggregate of fifty-three furnaces or cells, capable of dealing with 4,000 tons of refuse per week, the heat from which is utilized for generating power for various municipal purposes. The residual clinker from these furnaces, after being crushed, is used for concrete purposes to the extent of about 20,000 tons annually, and for some time past the practice has been adopted of constructing many of the footways with concrete paving slabs about two and a half inches thick, made from the refuse clinker, and manufactured by the Corporation at their destructor depôts, by the aid of Musker's patent concrete slab machinery.

As a further instance, showing how closely enlightened municipal progress is associated with the advances of science, it may be mentioned that the intelligence of the city, in the discharge of its many and varied duties, speedily saw the necessity and practical utility of a Municipal Bacteriological Department, the work of which largely consists in the routine bacteriological analysis of the water supplied to Liverpool, of the milk supply to the city, and of shell fish and preserved foods and meats. Investigations are also continually in progress upon disease problems in the community, such as the distribution and cause of outbreaks of diphtheria, typhoid, tubercle, diarrhoea, etc. Owing to the immense foreign trade of Liverpool, continual watch is maintained for cases of plague and cholera, with a view to forestalling a possible outbreak, and even the rats of the city are systematically kept under observation; and samples taken from ships, markets, warehouses, and sewers, are sent to the bacteriological laboratories for investigation.

To follow, if only in outline, all the departments of this great city's municipal activity, will not be possible upon the present occasion, but whether we review the leading features of its magnificent water supply system, or the many public street improvement schemes carried out for the accommodation and convenience of its great yet growing traffic, or the provision made in the erection of houses for the working classes of the city, or the baths, washhouses, markets, parks and open spaces provided for the health and comfort of the masses, we see throughout the same broad active spirit of municipal progress applying in the better light of the twentieth century, and for the good and convenience of the citizen, the accumulated wisdom of the past.

If we inquire further North, beyond the border, of the municipal progress made in Scotland, we find that its capital, the City of *Edinburgh*, or "the Modern Athens," and the "Empress of the North," as it has been aptly styled, has shown equal, if not even greater, activity in the public interests of the community it governs. The waters of the Leith have long been purged of the sewage of the city, which is now carried out to sea. In house sanitation Edinburgh has shown most commendable activity; house-to-house inspections have been carried out for many years, with the result that the drainage of its dwellings has been remodelled on the best modern lines, and the old cesspools and rubble drains of earlier days improved out of existence. In the matter of water supply the city is supplied from a very pure source by gravitation from the Pentland and Moorfoot hills, with a daily quantity of from 38 to 40 gallons per head of the population. An additional supply is also to be brought in from the Peebleshire hills. The authorities of Edinburgh have also done specially good work in the demolition and rebuilding of insanitary areas. Between 1893 and 1900 an aggregate of 15 acres of insanitary property was scheduled under the Housing of the Working Classes Acts, covering a total of 1,518 houses and affecting a population of 5,476 persons. The expenditure in the acquisition of old properties to date under the different schemes promoted has amounted to £129,341. Latterly, very successful attempts have been made to reconstruct old blocks of houses instead of demolishing them and building new houses on their site. Two blocks of dwellings, containing in all 28 houses have been recently reconstructed in this way at a cost of about 2½*d.* per cubic foot, and the Corporation has sanctioned a similar scheme for remodelling and reconstructing a large area in the centre of the city, known as "Greenside Area," embracing about 140 houses, at a probable cost of £13,700.

Enough, I think, has been said to show that the great mass of work, and the importance of the scientific, engineering, financial, and other interests involved in the operation of the municipalities of Great Britain, whether it be in the statesman, councillor, official, or manufacturer, calls for the application of the best talent and energy the world can produce in the solution of the many problems which force themselves to the front in the course of the great march of social and municipal progress.

We have now taken a somewhat rapid and cursory survey of the general bearings of our subject, and have also seen something of the nature and extent of the work of the leading British Municipal Authorities. We, therefore, next turn to notice, more particularly, the progress made in its several principal sections or departments, reviewing first the branch of—

Road Engineering and Maintenance

In the civilization and commercial development of all countries the builders of main lines of communication have invariably proved the most effective pioneers. The natural resources of the country are thus developed, and travelling, intercourse, industry, and commerce are rapidly set on foot; in fact, the road is so necessary an instrument of social well-being that in every new colony it is one of the first things to consider. John Ruskin, though no authority on road engineering, fully appreciated its influential agency in the development of a country's resources when he said: "All social progress resolves itself into the making of new roads."

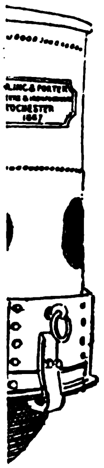
The history of the development of the roadways of this country from the original footpaths and horse-tracks (some of which perhaps formed the simple tracks of the original inhabitants) has been largely affected by the introduction from time to time of different modes of communication. From the time when the law compelled each parish to maintain its own roads by statute labour, and when the state of the roads of this country was notoriously bad, down to the present day, there have been events which have specially punctuated the different stages in the development of the roadways of this country. Among such influences, for example, have been the introduction of the turnpike system, 1653, and of "stage coaches" about the middle of the seventeenth century, which formed a new era in the history of travelling by road. The Bridgwater Canal in Lancashire gave a start to British barge canal navigation about the year 1759, and the first railway, the Stockton and Darlington, was opened in September, 1825. All these facilities have tended to greatly increase the general traffic and commerce of the country. Among the pioneer roadmakers of Great Britain are to be remembered the names of Metcalfe, Macadam, and Telford who did much to demonstrate to a listless public the essential features of good road construction.

Much improvement has been effected in the main roads of England and Wales since the year 1888, when their maintenance was provided for at the expense of the county in which they were situated, under the provisions of the Local Government (England and Wales) Act of that year. To-day the roads of this country are in a much better condition than at any previous date; but a new form of traffic has come—and has, I think, come to stay—amongst us, and is rapidly assuming such an importance as calls for the full energies of the road engineer to provide and maintain a surface suited to its requirements. I refer to the fast motor and cycle traffic, which has extended so rapidly throughout these islands during the past few years.

To meet the increasing requirements of present-day traffic in very many of our towns, the crooked ways and irregular street boundaries so dear to the archæologist and the historian have been "haussmannized" into straight avenues and rectilinear spaces, and modern roadmaking now enjoys a degree of skilled attention not formerly accorded thereto.

Down to the end of the eighteenth century our roadways had received little or no systematic attention, and engineers had not yet been induced to take the matter up on a scientific basis. Such repairs as were done were carried out in a very perfunctory manner by persons possessing no special knowledge of the work.

Telford first gave attention to the construction of roads in 1803–4, and his extensive practice in the building of new trunk roadways in England, Scotland and Wales, laid the foundations of good roadway construction which has been followed and largely elaborated since his time. His special object (as illustrated in the cross section, Fig. 1) was to ensure the entire separation of the "road metal" from the soil beneath by the use of a good "pitched foundation" or "bottoming," consisting of large pieces of durable stone, rubble, or other hard material. Other essential constructional features to be observed are—thorough under-drainage, the removal of all surface or storm water, and the coating of the hardcore foundation with a layer of hand-broken stone capable of withstanding the wear of the traffic and well consolidating the whole by rolling. In the setting out of a new line of roadway much care is obviously needed in the selection of the route to be taken, in order that the best gradients obtainable, having regard to reasonable economy of construction, may be secured. Since Telford constructed his first roadways a vast amount of work of this description has been carried out, and very great progress has been made in the improvement of both urban and rural roadways of this country.



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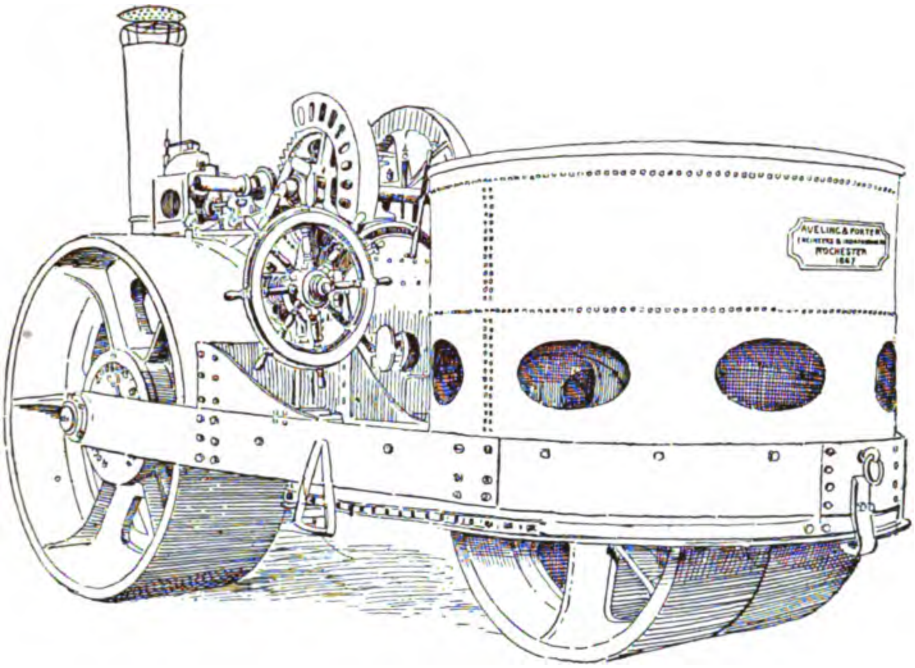


FIG. 16.—AVELING & PORTER'S STEAM ROLLER, 1867.

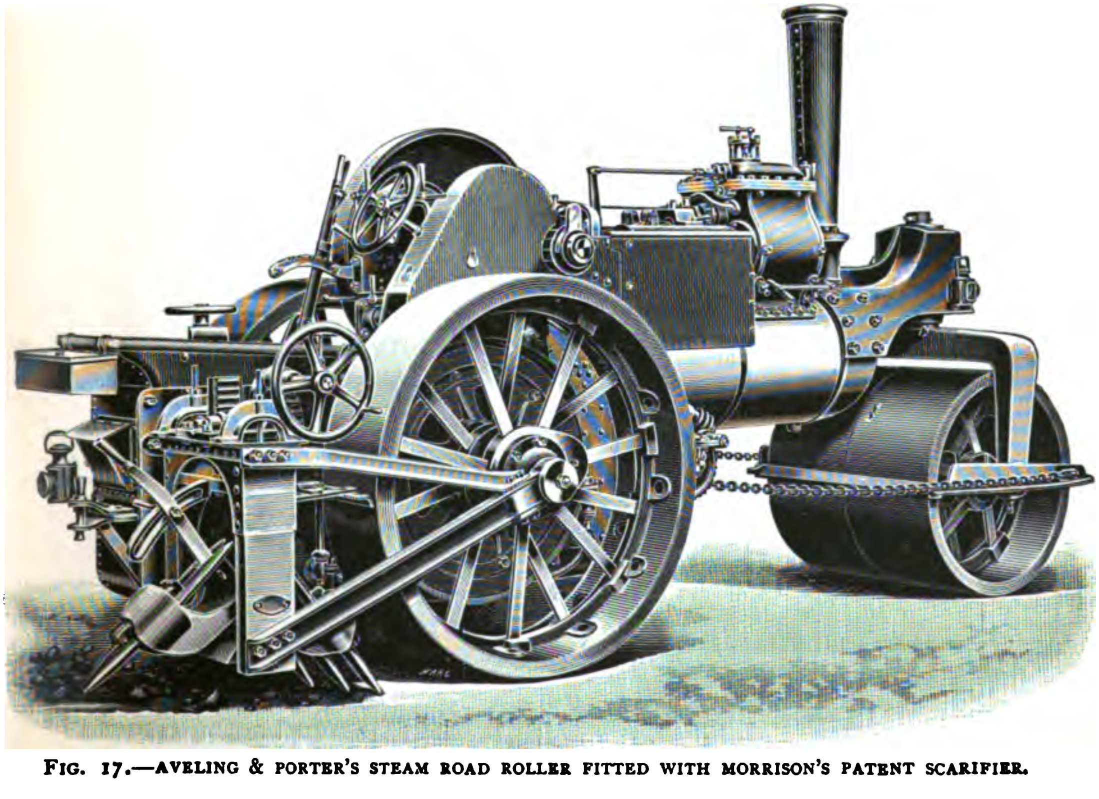


FIG. 17.—AVELING & PORTER'S STEAM ROAD ROLLER FITTED WITH MORRISON'S PATENT SCARIFIER.

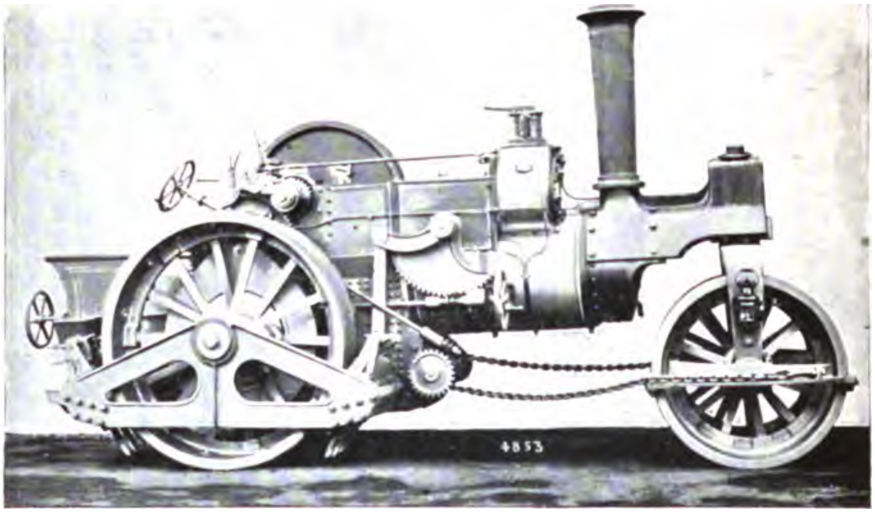


FIG. 18.—BURRELL & SONS' ROAD ROLLER FITTED WITH HOSACK'S SCARIFIER.

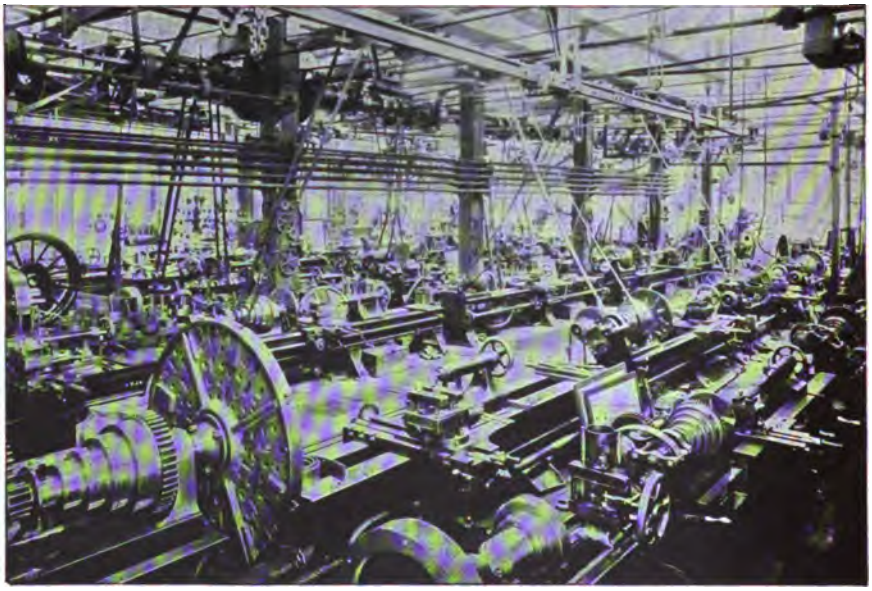


FIG. 19.—VIEW OF ONE OF MESSRS. BURRELL & SONS' TURNERY SHOPS.

ROAD ENGINEERING AND MAINTENANCE

Some of the constructional details of modern roadway engineering, as practised at the present day, are illustrated and described on Sheets I and II, which show the formation of hillside roadways, country macadam roadways, and town carriage ways paved with stone and wood.

In harmony with the progressive spirit of the age, the increase of population and commerce, and the extended use of the roads by vehicular traffic, the tendency throughout modern times has always been strongly towards higher standards of perfection in roadway construction and maintenance, and a fresh and decided impetus in this direction has been given of late by the rapid development of fast motor traffic.

The higher standards thus demanded have resulted in a general extension of the use of machinery in the repair and maintenance of both urban and rural roadways; and the productions of the British manufacturer in this connexion are to be found distributed widely over many countries of the world. Such plant principally consists of steam road rollers, road surface scarifiers, stonebreakers, and roadedge paring machines.

The illustration now given (Fig. 16) represents the first success of importance over previous attempts in the evolution of the steam road roller. This machine was supplied in 1867 by the well-known firm of Aveling and Porter, of Rochester, to Liverpool, and side by side with it is shown (Fig. 17) one of that firm's latest and best type of double-speed compound steam road rollers fitted with Morrison's patent " Scarifier."

This roller is an excellent machine for either town or country work. It weighs 10 tons and will roll a width of 6' 4". The engine is of about 6 horse-power nominal, and the boiler, which is made of special brand milled steel, is tested to 300 lbs. per square inch, for a working pressure of 150 lbs. The cylinders are steam jacketted, and the gearing throughout is of the best crucible cast steel. The roller wheels are of a specially prepared durable mixture of metals, and the roller is provided with a powerful screw friction brake, and other necessary accessories.

In the breaking up of macadam road surfaces previous to the laying of the new road material, "scarifiers" have now become very general. These machines effect a saving in cost as compared with manual labour of some ninety per cent., and the scarifying is more uniformly and expeditiously done. A ten-ton Aveling and Porter steam road roller will work the Morrison scarifier with ease, and will break up from 4,000 to 5,000 square yards of macadam surface per day.

In Fig. 18 is shown Hosack's patent scarifier attached to one of Messrs. C. Burrell and Son's road rollers, with which a good hard macadam road can be broken up for metalling at a cost of about ¼*d*. per yard super. This firm manufactures all classes of road-rolling and traction engine machinery, and a view of a portion of one of their workshops is shown in Fig. 19. Bomford's scarifier is illustrated in Fig. 20, attached to an improved single-cylinder 10-ton road-roller as made by Messrs. Clayton and Shuttleworth, of Lincoln, and Fig. 21 shows one of that firm's 12½-ton road rollers fitted with a crane for lifting 3 tons and transporting the weight suspended. The engine itself is compound, the cylinders being placed side by side, and are 5½" and 9" diameter,

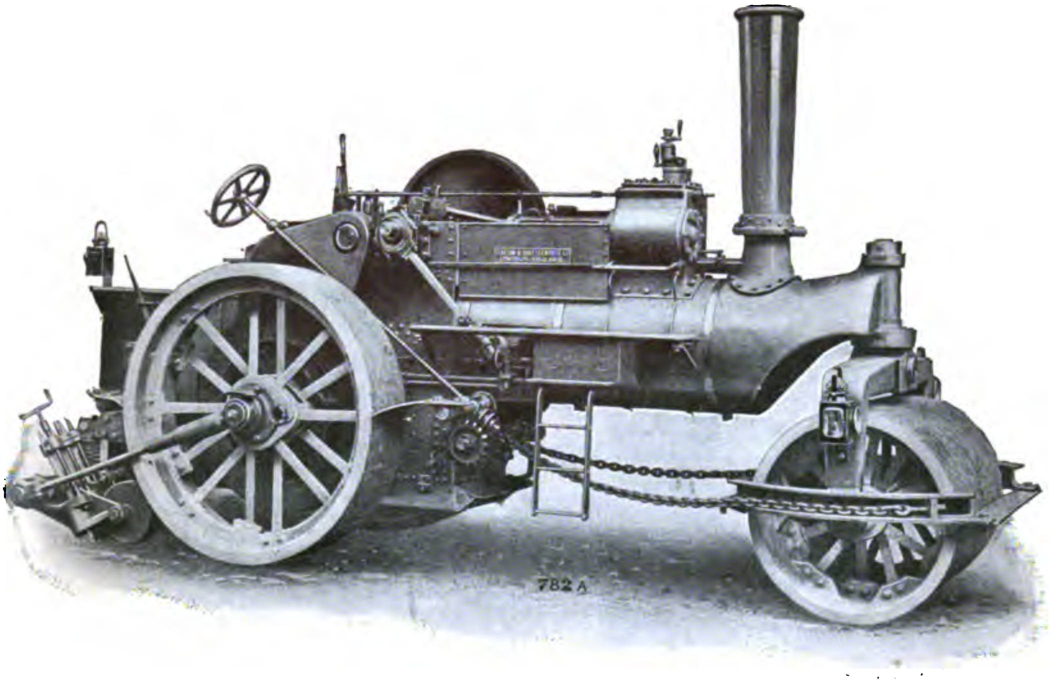


FIG. 20.—CLAYTON & SHUTTLEWORTH'S 10-TON ROAD ROLLER FITTED WITH BOMFORD'S SCARIFIER.

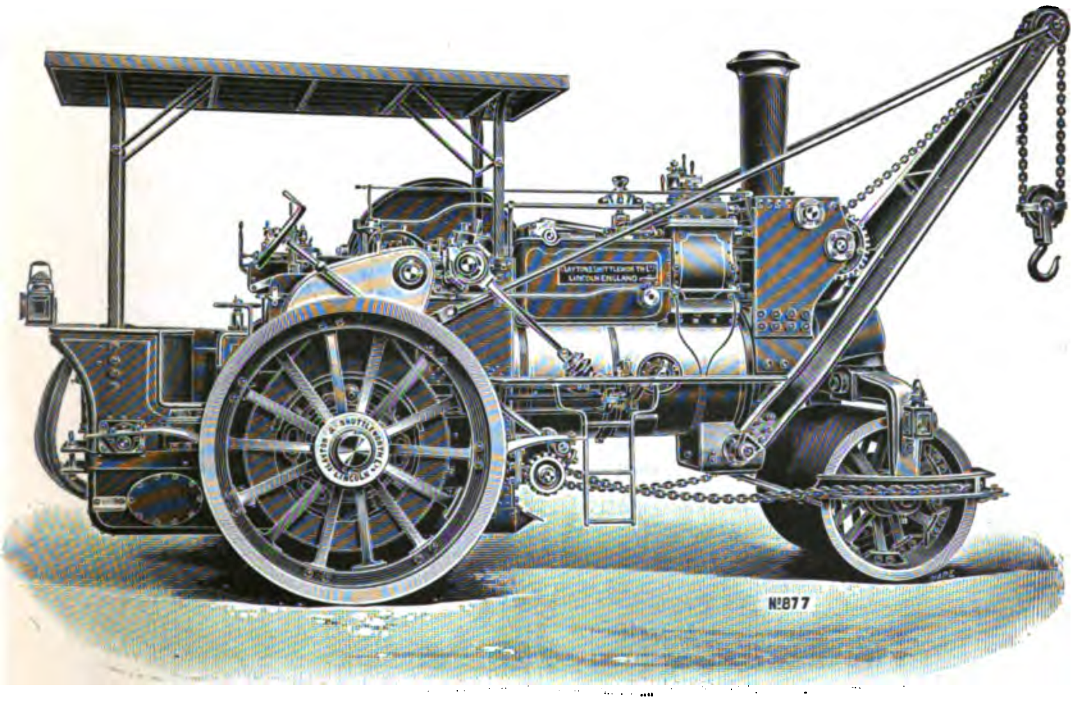


FIG. 21.—CLAYTON & SHUTTLEWORTH'S COMBINATION TRACTION ENGINE, ROAD ROLLER AND CRANE.

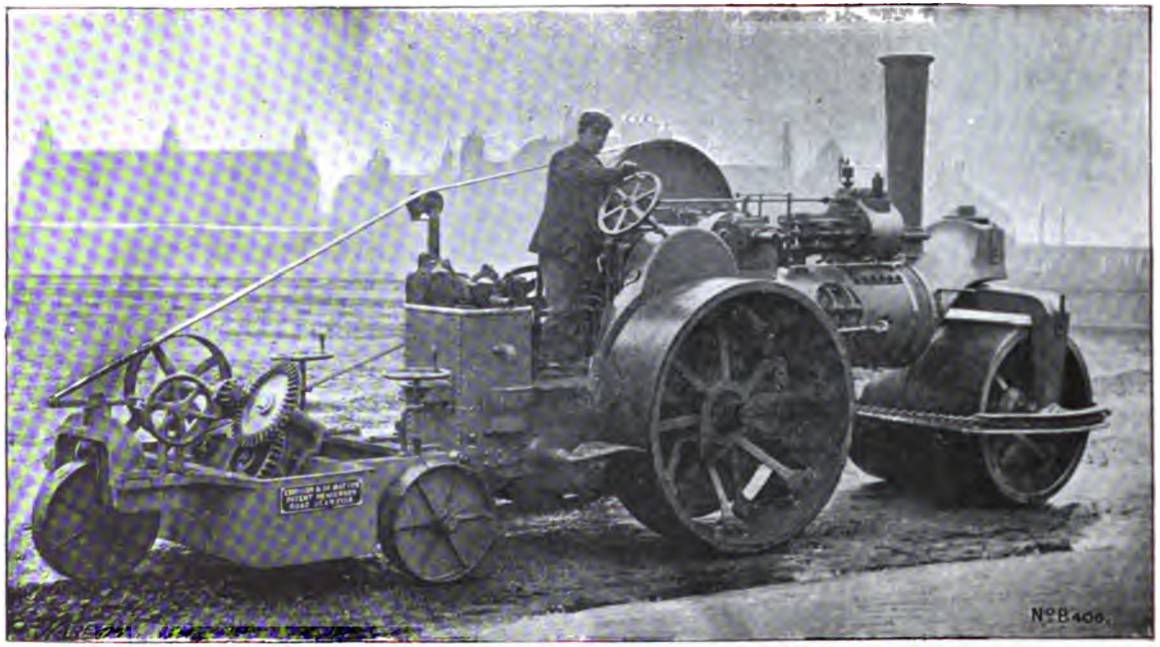


FIG. 22.—FOWLER-HENDERSON PATENT STEAM ROAD SCARIFIER, WITH REVOLVING DRILLS.

JOHN FOWLER & CO.'S COMBINED TRACTION ENGINE AND ROAD ROLLER.

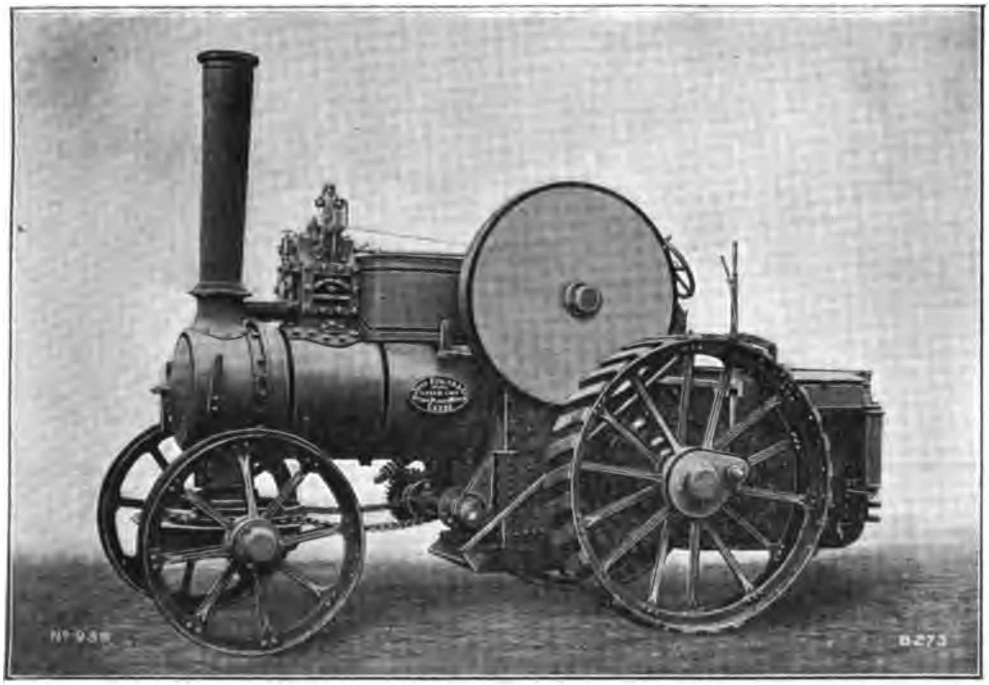


FIG. 23.—AS A TRACTION ENGINE.

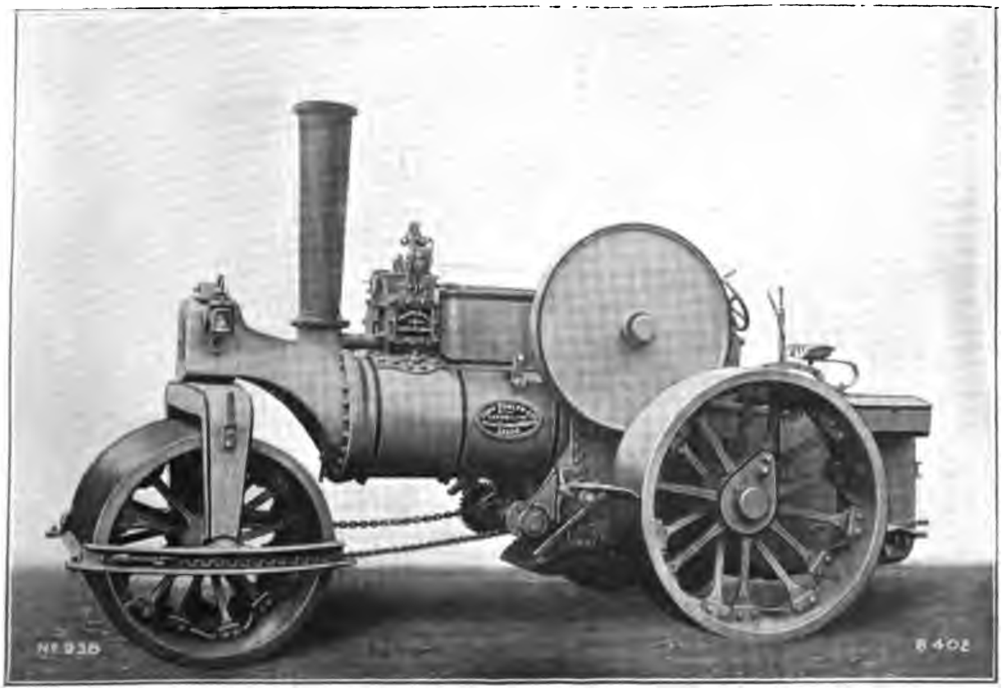


FIG. 24.—AS A ROAD ROLLER.

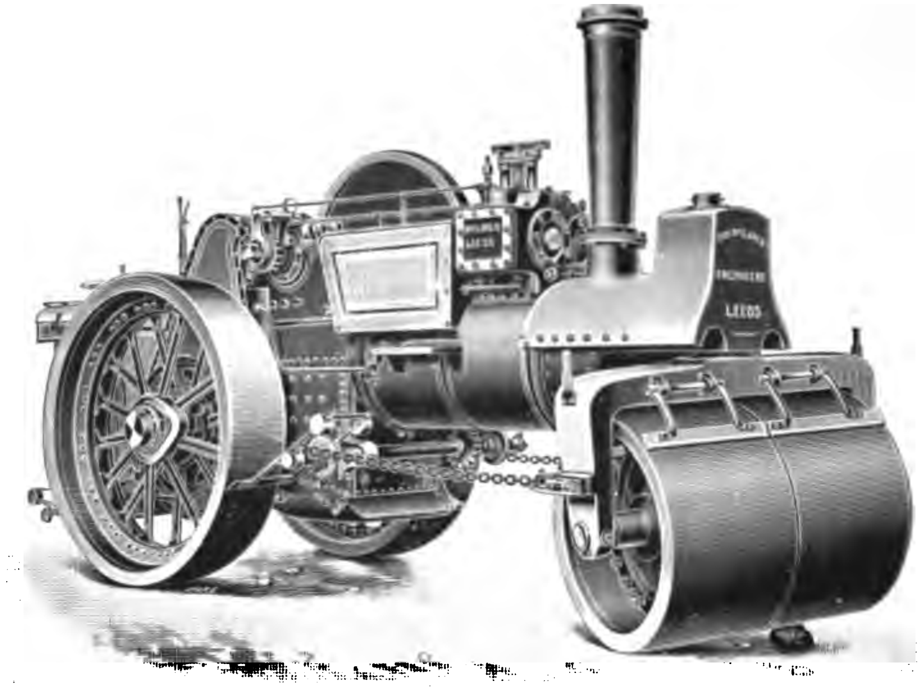


FIG. 25.—J. & H. MCLAREN'S ROAD ROLLER, SHOWING ANGULAR POSITION OF FRONT ROLLS WHEN PASSING OVER UNEVEN GROUND.

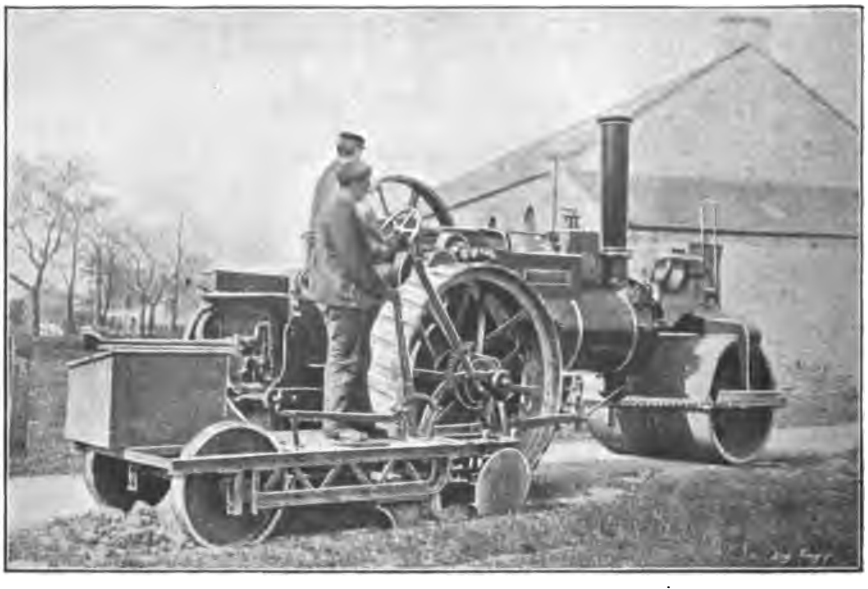


FIG. 26.—HOGG'S PATENT ROAD EDGE DRESSING MACHINE.

with a 12″ stroke. The whole forms a strong and serviceable piece of machinery. The machine shown in Fig 22 is the Fowler-Henderson steam road scarifier, with revolving drills driven by belt-power from an ordinary 10-ton roller. Messrs. J. Fowler and Co.'s combined traction engine and road roller is illustrated in Fig. 23, and Fig. 24 shows the same engine converted into a steam roller. Messrs. J. & H. McLaren's improved roller (Fig. 25) shows the angular position of the front rolls when passing over uneven ground. Other well-known makers of road-rolling plant are Messrs. Marshall, Sons, and Company, Gainsborough, and Messrs. T. Green and Sons, of Leeds.

A road-edge dressing machine (Fig. 26) has recently been invented by the County Road Surveyor of Elgin. It is attached to a road roller or engine for the purpose of paring or dressing the edges of public roads. The portion trimmed at one operation may vary from 6″ to 30″ in breadth and from 1″ to 10″ in depth. The machine is made by Messrs. John Fowler and Company, of Leeds.

Many highway authorities quarry and prepare their own roadway metalling, which is either broken by hand or by machine. The cost of production by machine is usually some 40 to 50 per cent. less than by hand, and the material is at the same time well screened and assorted to the different sizes required. The fine grit produced is also a good material for binding a newly laid coating of macadam. There are many useful machines now on the market. The breaker made by Messrs. W. H. Baxter, Limited, of Leeds (Fig. 27), has been extensively used for many years, and has proved a very satisfactory apparatus as regards its breaking capacity, quality of material produced, economy of working and minimum of wear and tear.

> An important feature of this machine is its "knapping motion" suggested by practical experience, the effect of which is to break the stone without crushing and damaging it as a road metal. The portable type of machine with the automatic screening and loading appliances has undoubtedly supplied a great want in districts where stone has to be procured from different quarries near the roadways to be repaired. Baxter's stone-breaker is made in several sizes; the smallest machine, with a mouthpiece of 6″ × 4″, has a guaranteed breaking capacity of 1·5 tons per hour, and the largest size, known as a 24″ × 15″ machine, delivers 16 tons per hour.

Fig. 28 is a view of one of these machines fixed on brick foundations with automatic screening and elevating arrangement.

A section of Messrs. Mason Bros.' latest patent improved lever cracking-motion stone breaker is shown in Fig. 29, and the "Robey" breaker, fitted with steel plate screen, driven from the crusher shaft, in Figs. 30 and 31. The latter machine is made in sizes from 9″ × 5″ mouthpiece up to 24″ × 20″ and breaks from 2·5 tons to 18 tons of metal to pass a 2″ ring per hour. The brake horse-power required is from 5 b.h.p. to 60 b.h.p., according to the size of machine. Fig. 32 is a section of Messrs. R. Broadbent & Son's stone breaker fitted with patent "drawback motion," swinging from a fulcrum at the top of the main frame, and Figs. 33 and 34 show the Blake-Marsden lever hand-hammer-action stone-breaker, with elevator, overhead screening and loading appliance for filling carts or trucks without hand labour, fitted also with Marsden's patent safety coupling.

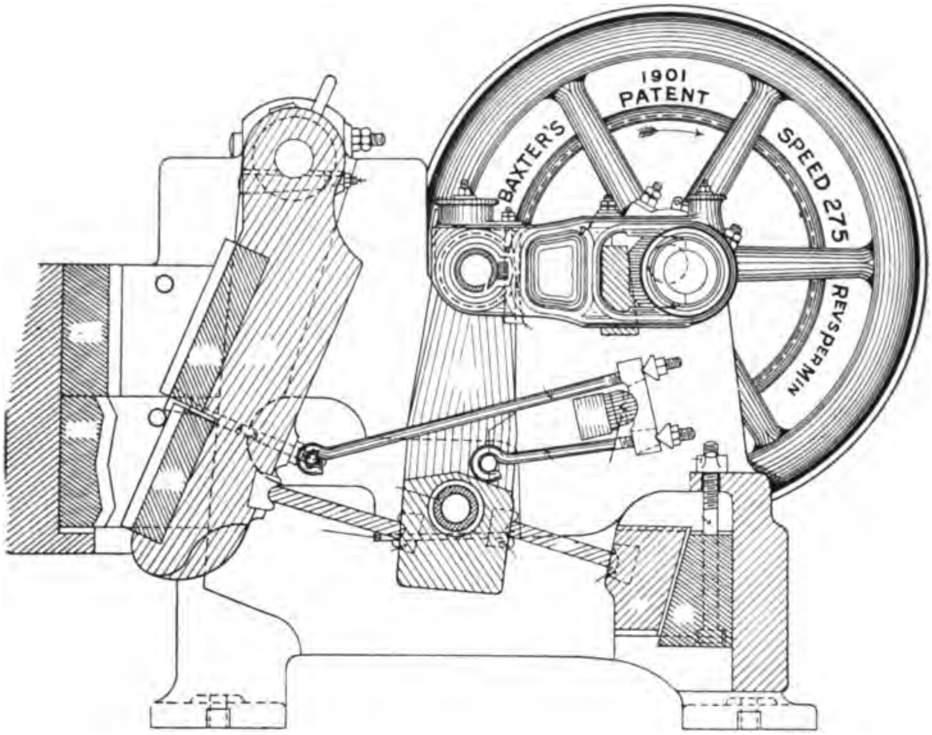


FIG. 27.—PART SECTIONAL VIEW OF BAXTER'S PATENT STONE BREAKER.

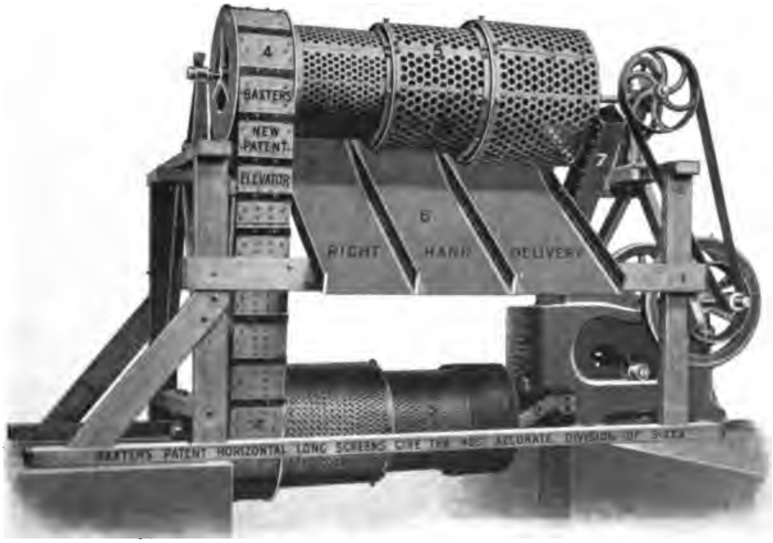

4
BAXTERS
NEW
PATENT
ELEVATOR
5
6
RIGHT HAND DELIVERY
7
BAXTER'S PATENT HORIZONTAL LONG SCREENS GIVE THE MOST ACCURATE DIVISION OF SIZES

FIG. 28.—BAXTER'S STONE BREAKING MACHINE WITH AUTOMATIC SCREENING AND LOADING ARRANGEMENTS.

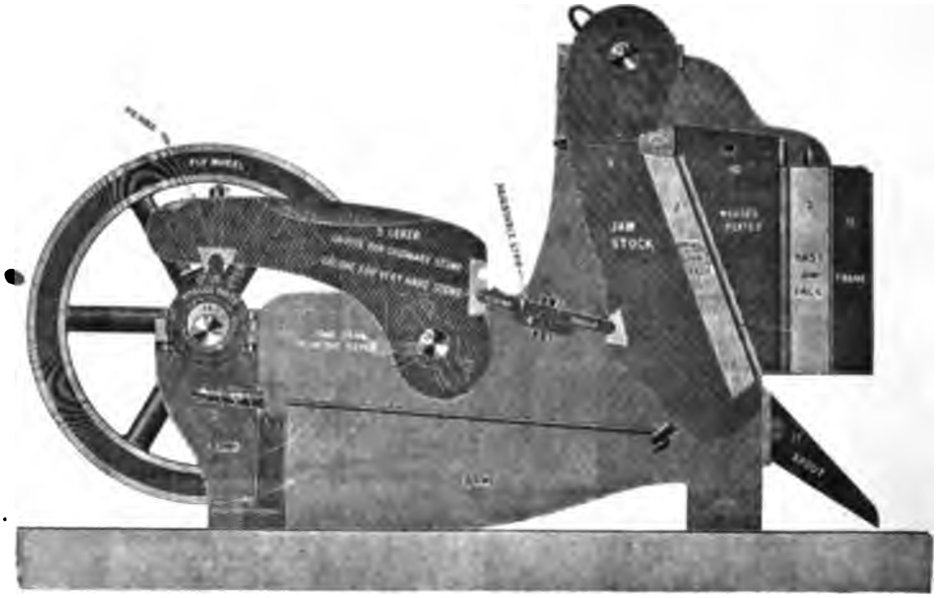
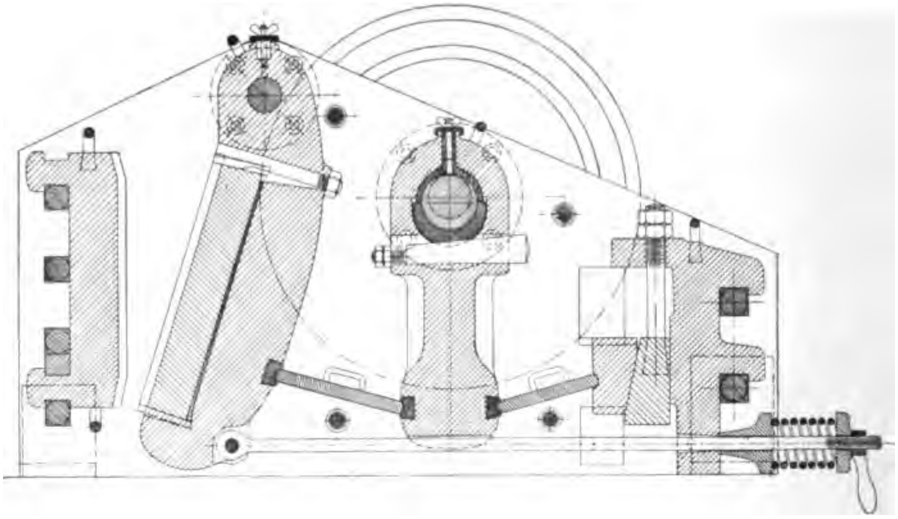


FIG. 29.—SECTIONAL VIEW OF MASON BROS.' PATENT LEVER STONE BREAKING MACHINE.



SECTIONAL ELEVATION OF THE

ROBEY STONEBREAKER

FIG. 30.

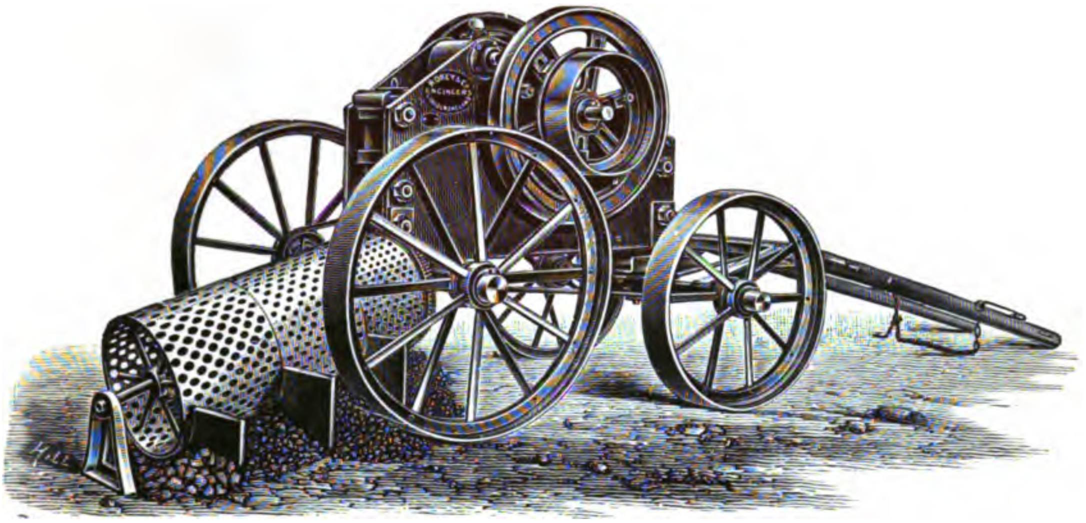


FIG. 31.—ROBEY & CO.'S PORTABLE STONE BREAKER.

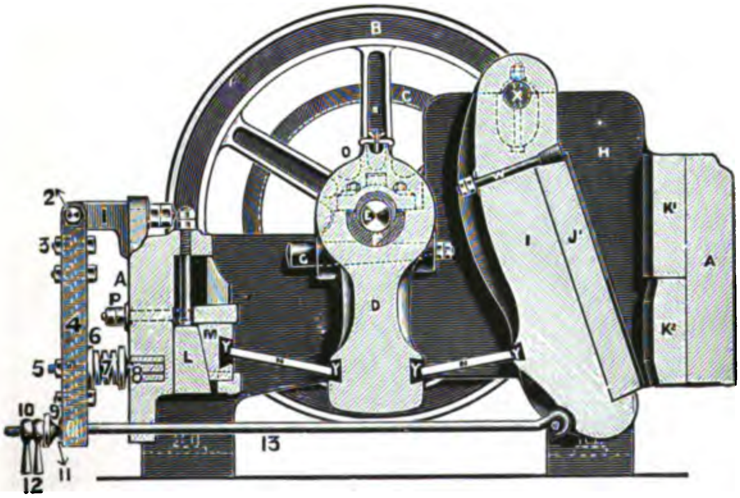


FIG. 32.—PART SECTIONAL VIEW OF BROADBENT & SONS' STONE BREAKER.

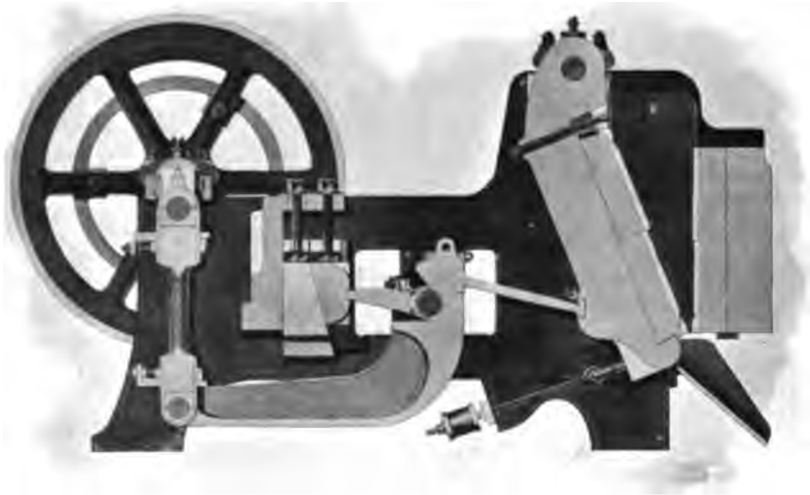


FIG. 33.—SECTIONAL VIEW OF BLAKE-MARSDEN HAND-HAMMER ACTION STONE BREAKER.

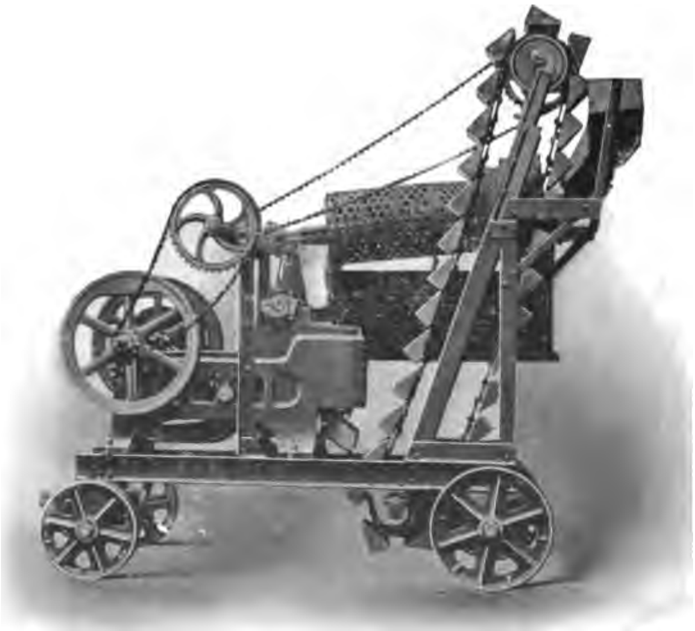


FIG. 34.—PORTABLE TYPE OF BLAKE-MARSDEN STONE BREAKER.

Concurrently with the increased care and attention given to the maintenance of macadam roadway surfaces have been many improvements in the production and laying of artificial materials for the pavement in urban areas of carriageways and footways. In London and other towns the compressed and mastic asphaltes have been largely used for carriageways and footways respectively, as laid by the Limmer Asphalte Paving Company, the Val de Travers Asphalte Company, and others. The Acme Wood Flooring Company, amongst others, are specialists in all classes of wood paving, including Jarrah, Karri, and other West Australian hardwoods, American red gum, etc.

A good pavement for either carriageways or footways has also been successfully introduced and tested in London in situations subjected to heavy traffic by the Sanitary Block and Tile Pavement Company. This pavement consists of blocks, measuring about 4″ x 12″ x 4″ deep, made of a mechanical mixture of asphalte and crushed trap-rock, granite, hard limestone, or other suitable material, and subjected to a pressure of 125 tons whilst at a temperature of about 300° Fah. The pavement affords a good foothold to horses, is of a durable nature, non-absorbent, and comparatively noiseless. The entrance to Hyde Park at the Marble Arch, Carlos Place (Grosvenor Square), and other places, have been paved with this material. The blocks are laid (Fig. 35) on a 4½″ concrete bed overlaid with ½″ of mortar, and tiles of 2¼″ thickness of the same material are laid on a 1½″ sand bed for forming footways.

Many artificial stone paving slabs are also available for the pavement of footways, and large quantities have been laid for many years in this country under conditions of very heavy traffic, such as the Victoria and indurated stone, adamant, imperial, Stuart's granolithic paving, and Ellis' silicated concrete stone; Hamblet's terra-metallic pavings, curbs, and channels, are also of great strength and durability. The residual furnace clinker from the destructor stations of many Corporations is also manufactured into paving slabs and bricks; and for this purpose, after the ingredients of the slab have been properly prepared and placed in a suitable mould, the slab is then subjected to a high pressure applied by means of a hydraulic press. Machines for this purpose are manufactured by Messrs. C. and A. Musker, Liverpool (Fig. 36); Messrs. H. Berry and Company, Leeds (Fig. 37); and Messrs. Fielding and Platt, of Gloucester (Figs. 38 and 39).

The point has long been appreciated in all well-governed towns that to properly maintain the road surfaces and derive the full benefits from the efforts of the roadmaker it is essential that streets and roadways be efficiently scavenged in a systematic manner, otherwise much deterioration of the surface will result. The energies of manufacturers in this department have kept our municipalities well supplied with up-to-date and improved appliances and plant of every description, and have for some few years past introduced the road motor for municipal haulage purposes, street watering, etc. Fig. 40 shows the standard steel-tip wagon as supplied by the Thornycroft Steam Wagon Company of Basingstoke for the purpose of collection of street and household refuse. Its

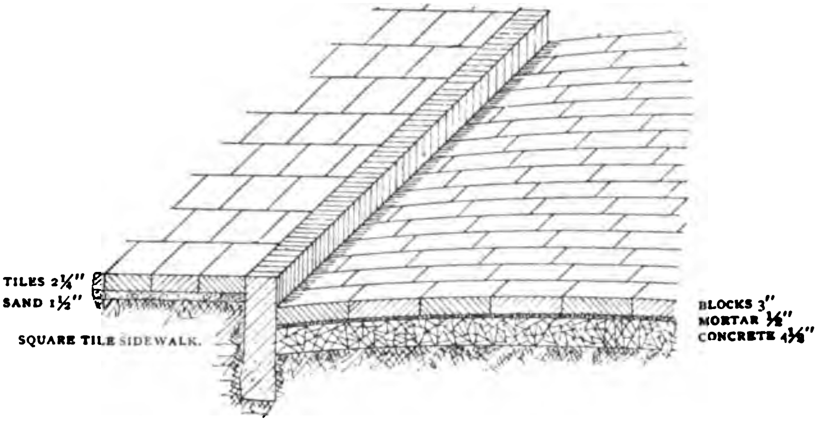


FIG. 35.—CROSS SECTION OF FOOTWAY AND ROADWAY PAVED WITH SANITARY BLOCK TILE PAVEMENT.

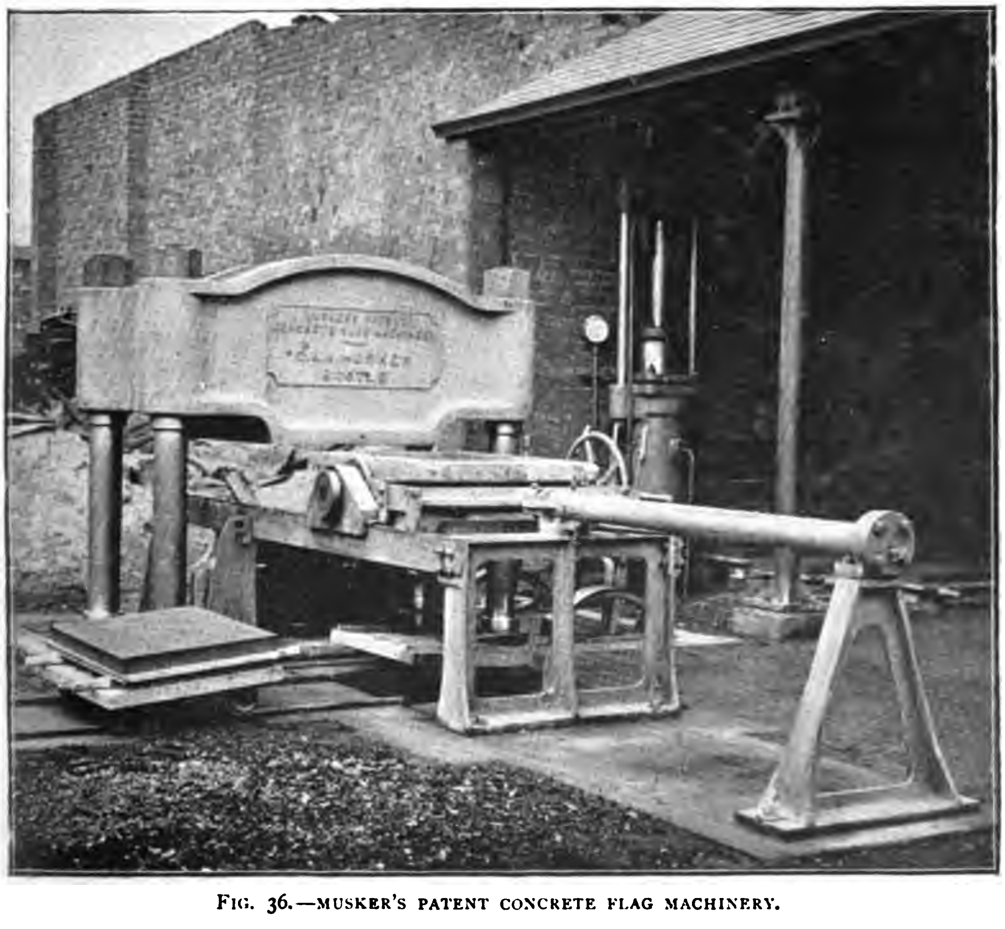


FIG. 36.—MUSKER'S PATENT CONCRETE FLAG MACHINERY.

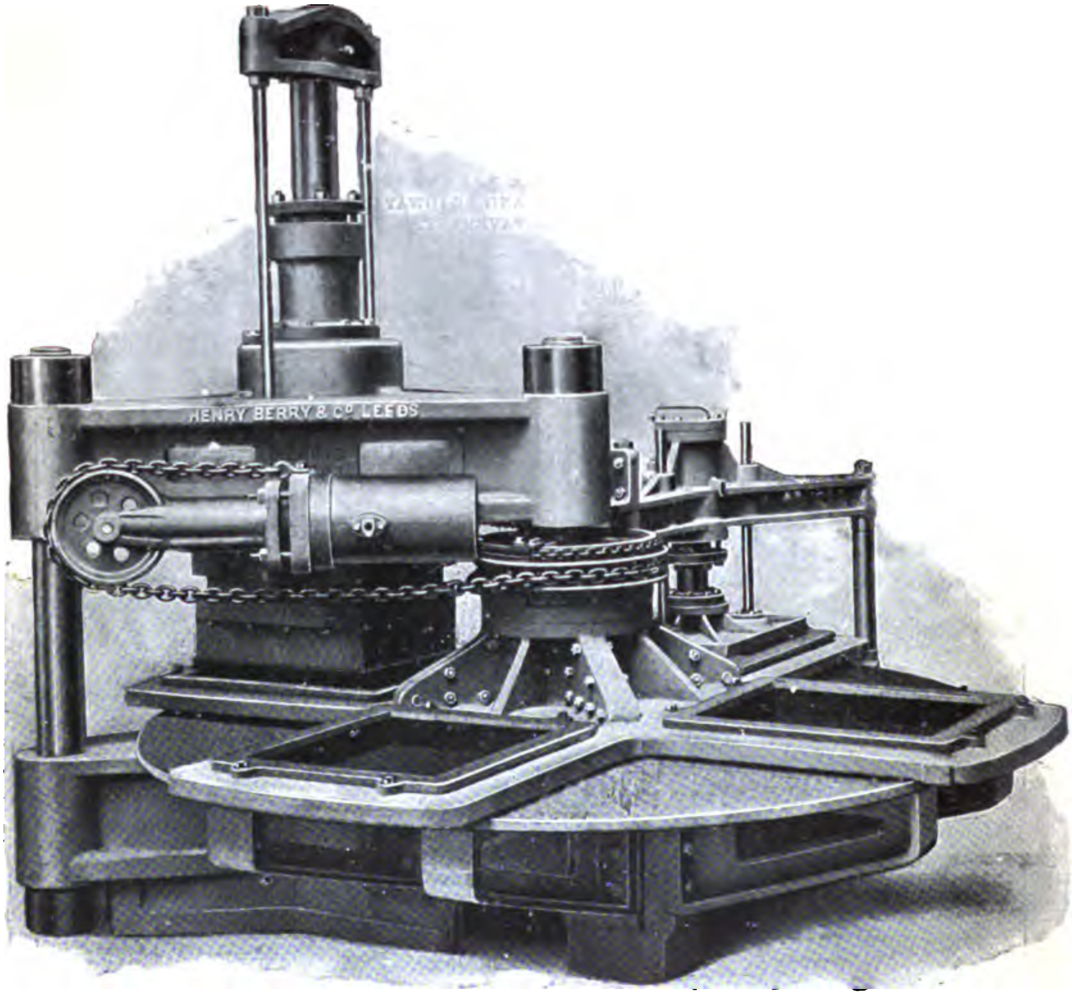


FIG. 37.—HENRY BERRY & CO.'S ARTIFICIAL FLAG MACHINERY.

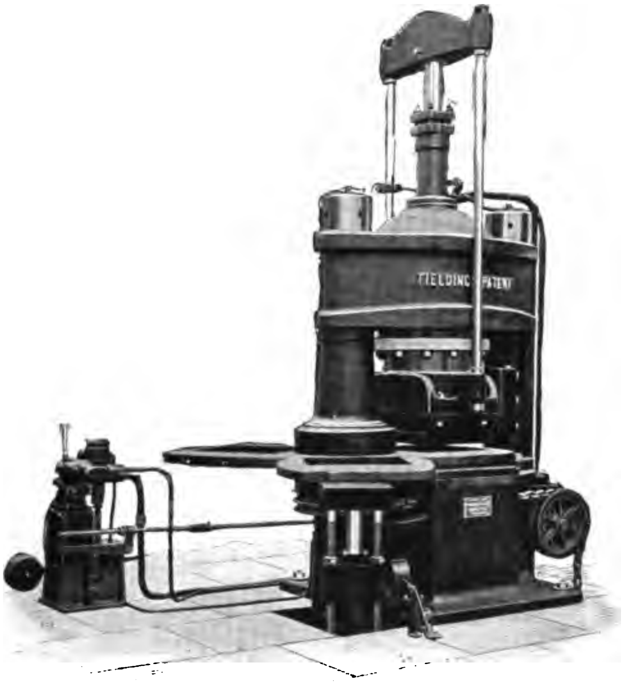


FIG. 38.—FIELDING & PLATT'S LATEST TYPE THREE-MOULD STONE PRESS, AS SUPPLIED TO OLDHAM COUNCIL.

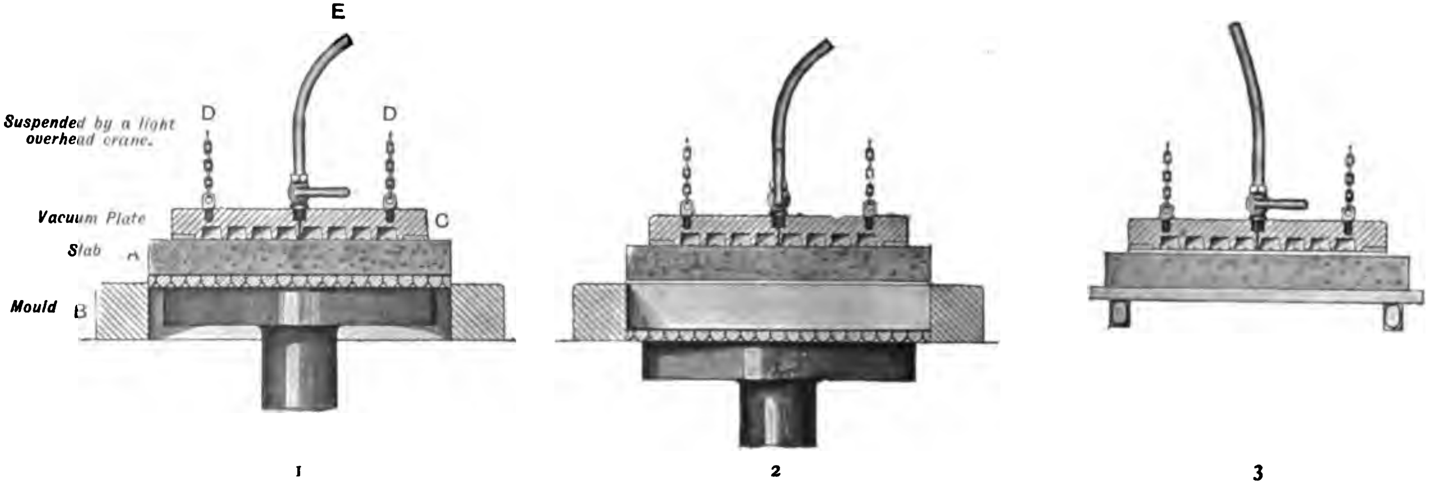


FIG.—39.—DIAGRAM OF FIELDING'S PATENT VACUUM GEAR FOR CARRYING THE ARTIFICIAL SLABS. E IS A FLEXIBLE PIPE CONNECTING WITH A VESSEL IN WHICH A PARTIAL VACUUM IS CONSTANTLY MAINTAINED.

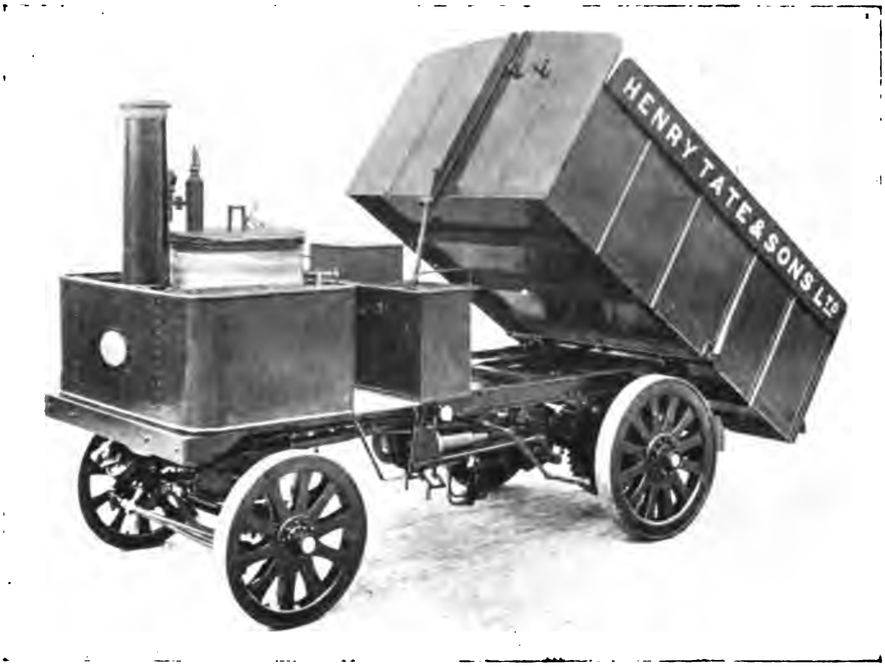


FIG. 40.—LATEST TYPE OF THORNYCROFT MUNICIPAL STEAM MOTOR WAGON.

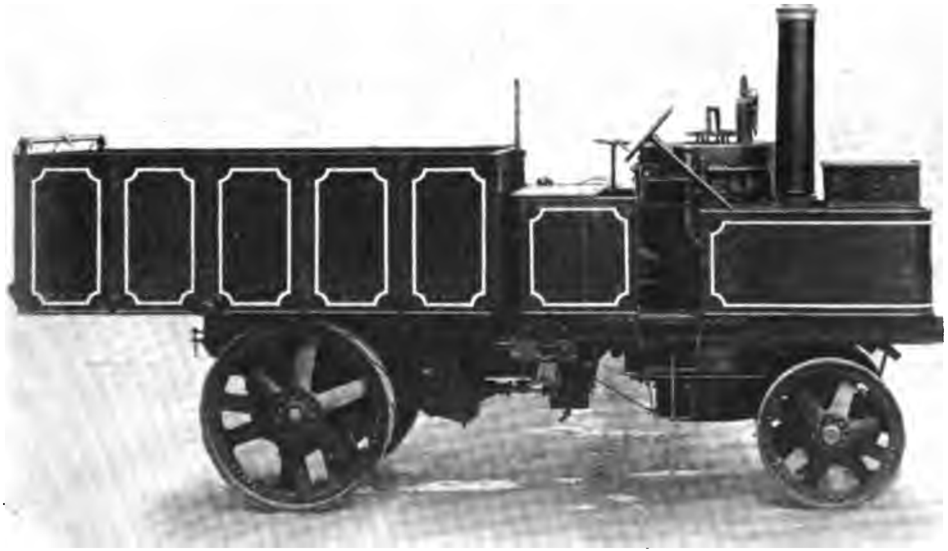


FIG. 41.—THORNYCROFT COLONIAL TYPE OF MUNICIPAL STEAM MOTOR TIPPING WAGON.

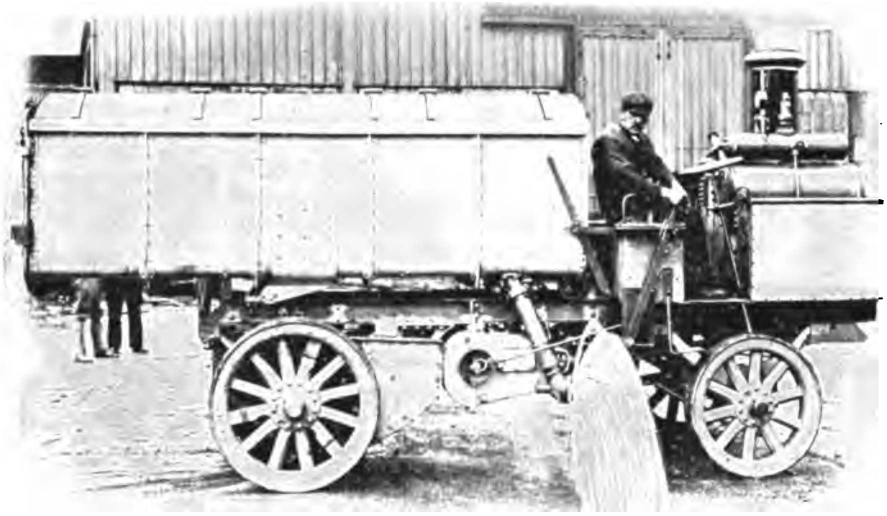


FIG. 42.—SAVAGE BROS.' PATENT COMBINED STEAM SANITARY WAGON.

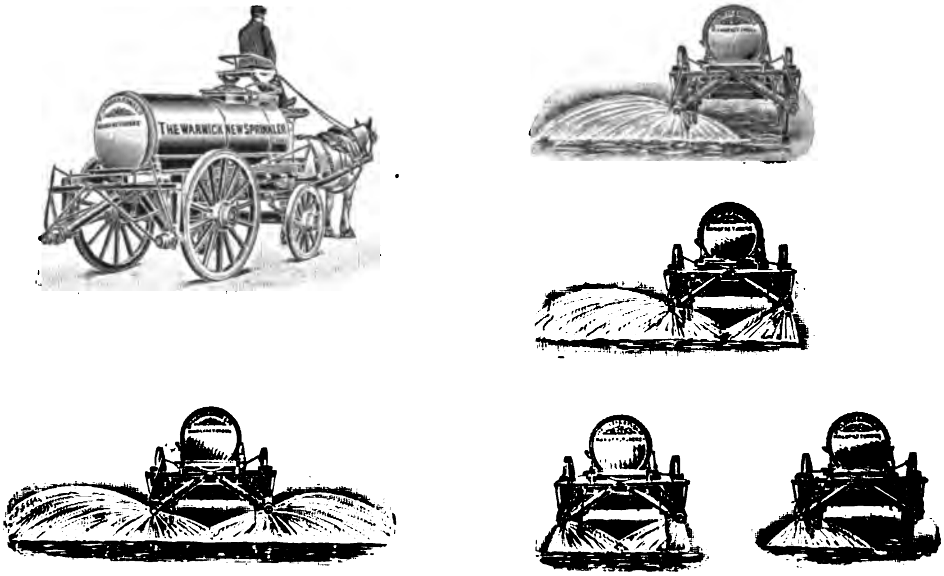


FIG. 43.—THE NEW "WARWICK" SPRINKLER BY WM. GLOVER & SONS.

capacity is 7 cubic yards, and the engine is capable of indicating 25 horse-power at 450 revolutions.

> This firm's standard heavy wagon carries 3 tons and hauls a further 2 to 3 tons on a trailing vehicle when required. Welsh coal, coke, or oil is used as fuel, and sufficient is carried for a full load run of 40 to 50 miles. Water for 15 to 20 miles is also carried, and a daily journey of 35 to 40 miles can be relied on 5 days per week or about 260 days a year.

In England the total cost under ordinary circumstances of carrying one ton one mile, inclusive of depreciation, interest, wages, fuel and repairs, has been found to be about 3·5 pence. Fig. 41 shows a municipal tipping wagon of Thornycroft's Colonial type, several of which have been supplied to the South African Colonies and elsewhere.

Other firms engaged in the heavy motor industry, which is being largely adopted for municipal and other traffic of this country, are Messrs. C. and A. Musker, Liverpool; Mann's Patent Steam Cart and Wagon Company, Leeds; Simpson and Bibby, Manchester; Lancashire Steam Company, Preston; the Mechanical Transport Company; the Straker Steam Vehicle Company, Cannon Street, E.C.; and Messrs. T. Coulthard and Co., Ltd., of Preston, Lancashire.

Of other typical examples of British municipal scavenging plant may be mentioned the combined steam sanitary wagon (Fig. 42) of Messrs. Savage Bros., King's Lynn, which is adaptable for purposes of either watering, sweeping, or collection of dust; the new "Warwick" sprinkler (Fig. 43) of William Glover & Sons, which will spread any width from 2 feet up to 22 feet; the "Champion" dust van (Fig 44), with sliding covers and wind guards—a vehicle which was awarded the London County Council premium in a competition which was open to all England; and the "Albion" street sweeping machine (Fig. 45), made by Messrs. Baker and Sons, Compton, Berks.

In carrying out new road works in country districts, or in connexion with Colonial work, it frequently becomes necessary in the completion of accessory details connected therewith, to erect a light class of footbridge across neighbouring streams, ravines, railways, canals, etc., in order to give free communication to or across the main trunk roadway. For such a purpose Harper's steel rope suspension bridges are very well suited—one of which is shown in the accompanying view (Fig. 46). The foundation anchor blocks of this description of bridge are formed of cement concrete, in which are embedded the iron rails and eye-rods for attachment of the main ropes. The four supporting pillars of the bridge are formed of open steel lattice work, or columns, and are set on stone or concrete piers prepared for them. The ropes are made from the best patent galvanized steel wire, and the core of the rope is of wire, to prevent elongation after erection. The flooring is of wood crossbearers, of a thickness suited to the width of footway.

These bridges will carry a distributed load of 160 lb. to the square foot, or about twice the weight of all the people who could stand thereon at one time, and additional strength can of course be obtained if desired. They are made in spans of from 50 ft. to 300 ft. and from 4 ft. to 6ft. wide, and are suitable for the transit of foot passengers, cattle, sheep, saddle horses, etc. The bridge is specially adapted for

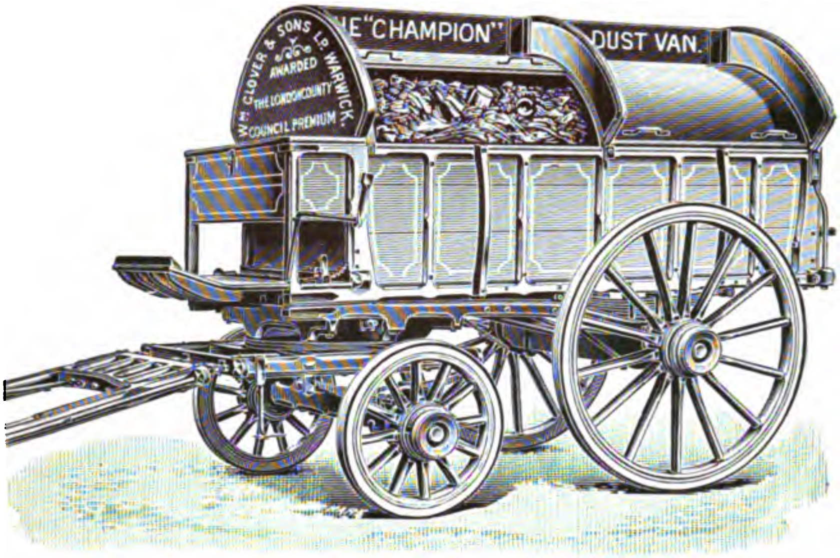

E "CHAMPION"
DUST VAN.
WM. GLOVER & SONS LD. WARWICK.
AWARDED
THE LONDON COUNTY COUNCIL PREMIUM

FIG. 44.—THE "CHAMPION" DUST VAN BY WM. GLOVER & SONS.

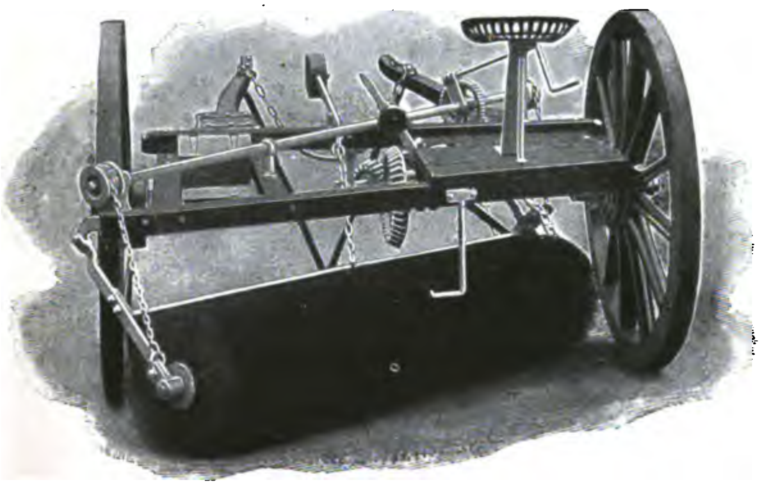


FIG. 45.—"ALBION" STREET SWEEPING MACHINE BY T. BAKER & SONS.

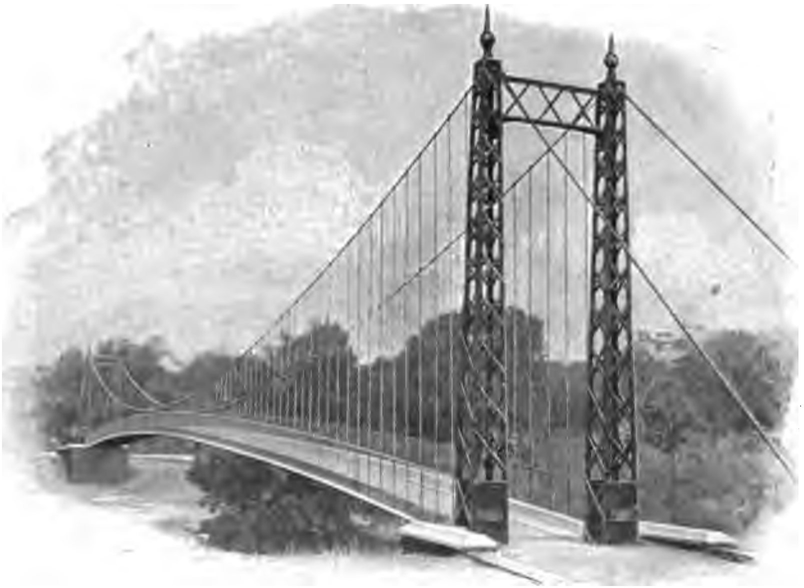


FIG. 46.—STEEL ROPE SUSPENSION BRIDGE BY LOUIS HARPER, OF ABERDEEN WIDTH, 6 FEET; SPAN, 210 FEET.

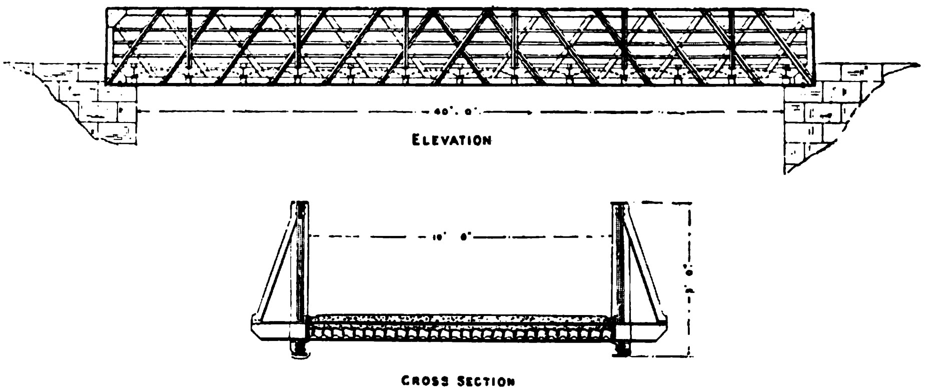


FIG. 47.—OPEN GIRDER TYPE OF ROAD BRIDGE BY A. & J. MAIN & CO.

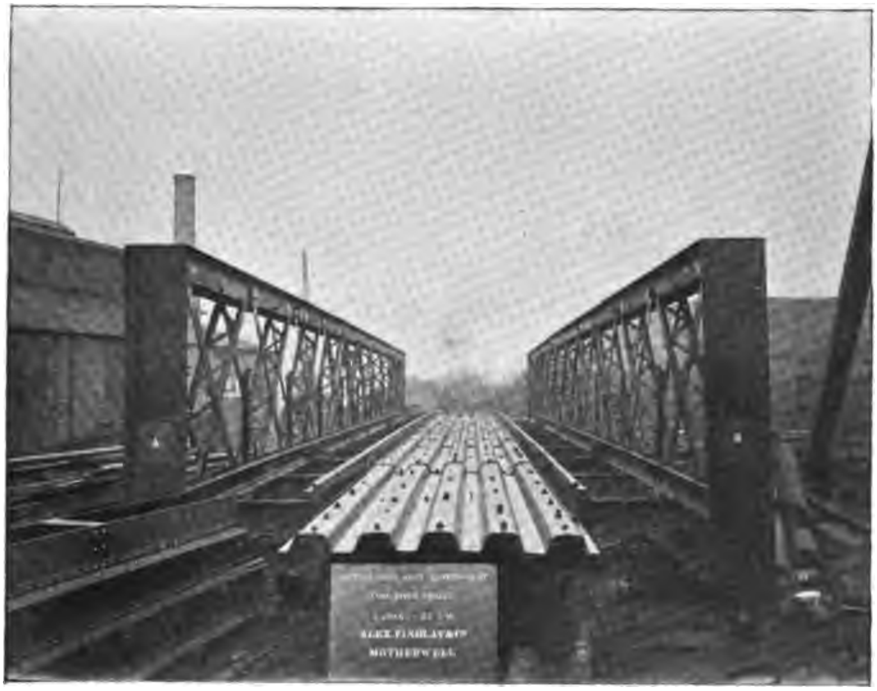


FIG. 48.—BRIDGE TO CARRY ROAD OVER THE TINA RIVER SOUTH AFRICA, BY MESSRS. ALEXANDER FINDLAY & CO. OF MOTHERWELL, SCOTLAND.

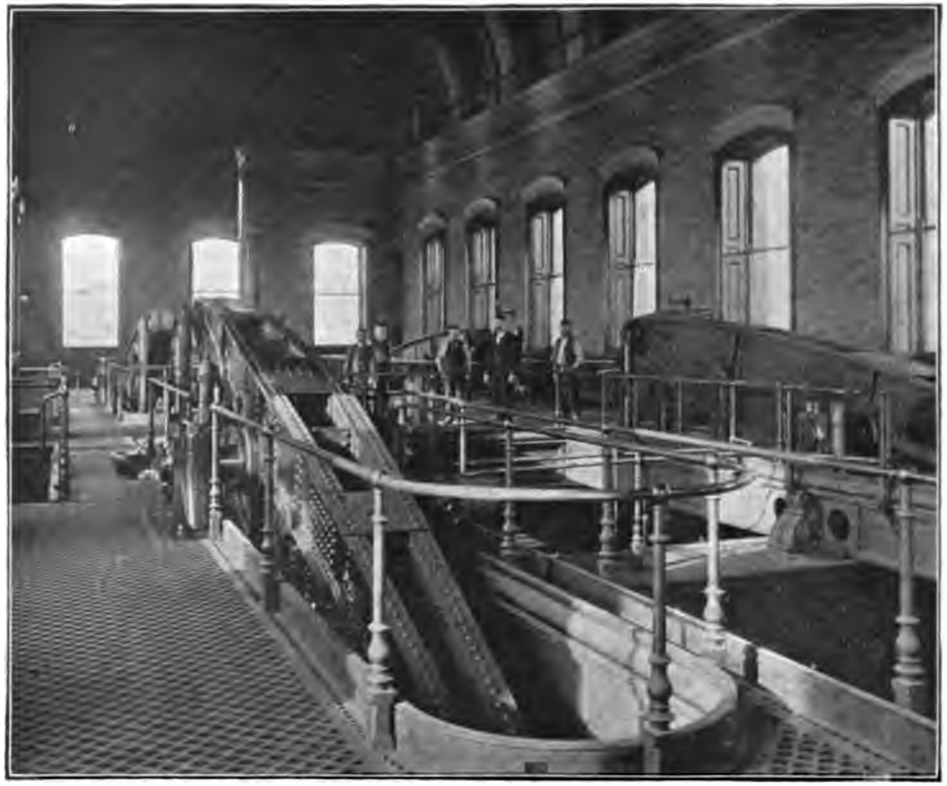


FIG. I.—LONDON MAIN DRAINAGE—WESTERN PUMPING STATION. BEAM FLOOR AND ENGINE HOUSE.

export, all the parts being light for transit, and has been supplied to several Government Departments.

Another useful form of bridge is that supplied by Messrs. A. & J. Main and Company, and illustrated in Fig. 47. It is of the open girder type, is suitable for vehicular traffic, and for spans from 30 ft., upwards, with a width of roadway from 10 ft., and upwards. The roadway is carried on concrete laid on curved corrugated steel plates, supported by cross and longitudinal steel girders.

A good view of a larger type of road bridge is given in Fig. 48, which illustrates the construction of a steel lattice girder bridge erected for the Cape of Good Hope Government by Messrs. Alexander Findlay & Co., of Motherwell, to carry a road over the Tina Tiver in South Africa. The bridge consists of three spans of 99′ 6″ clear, each carried by two main lattice girders with double-web looms. Ten fish-bellied single-web cross-girders to each span carry the "Findlay" type steel trough flooring, 6″ deep, which runs longitudinally, as shown, to form the middle roadway, on each side of which is a footpath 4′ in width. The main girders rest on expansion rollers at one end, and the whole steelwork of the bridge weighs about 160 tons.

APPENDIX TO LECTURE I

CLASSIFIED LIST OF BRITISH MANUFACTURERS INTERESTED IN ROAD ENGINEERING AND MAINTENANCE

ASPHALTE.

Bradshaw & Co.	52, Queen Victoria Street, E.C.
Faldo, T.	283, 285, Rotherhithe Street, London, S.E.
Hobman, A. C. W., & Co.	Cliftonville, South Bermondsey, S.E.
Limmer Asphalte Paving Co.	2, Moorgate Street, London, E.C.
Payton, J. I.	Colwick Road, Nottingham.
Salter, W., & Co.	587 and 589, Harrow Road, Kensal Green, W.
Wainwright, J., & Co., Ltd.	Downside Granite Quarries, Shepton Mallet.

BRICKS, TILES, ETC.

Boote, T. and R., Ltd.	The Patent Tile Works, Burslem.
Buckley Brick and Tile Co., Ltd.	Buckley, via Chester.
Craig, J. and M., Ltd.	Kilmarnock.
Dennis, Henry	Ruabon.
Griffiths, Wm.	41, Hamilton House, Bishopsgate Street Without, E.C.
Hamblets, Ltd.	West Bromwich.
High Brooms Brick and Tile Co.	High Brooms, Tunbridge Wells.
Lawrence, T., & Sons	Bracknell, Berks.
Place, J., & Sons, Ltd.	Darwen, Lancashire.
Stanley Brothers, Ltd.	Nuneaton.
Tucker, G., & Son	Loughborough.
Woolliscroft, G., & Son	Hanley.

BRIDGES.

Abbot, J., & Co., Ltd.	Gateshead-on-Tyne.
Armoured Concrete Construction Co.	109, Victoria Street, S.W.
Arrol, Sir W., & Co., Ltd.	Dalmarnock Ironworks, Glasgow.
Arrol's Bridge and Roof Co., Ltd.	Germiston Works, Glasgow.

Birch, J., & Co., Ltd.	10, Queen Street Place, E.C.
Brandon Bridge-Building Co., Ltd.	Motherwell, near Glasgow.
Butterley Co., Ltd.	Derby.
Cleveland Bridge and Engineering Co., Ltd.	Darlington.
Clyde Structural Iron Co., Ltd.	Clydeside Works, Glasgow.
Dalziel Bridge and Roof-Building Co., Ltd.	Motherwell, near Glasgow.
Darlington Wagon and Engineering Co., Ltd.	Darlington.
De Bergue & Co., Ltd.	Strangeways, Manchester.
Dorman, Long & Co., Ltd.	Middlesbrough.
Finch, E., & Co., Ltd.	Chepstow.
Findlay, A., & Co.	Motherwell, near Glasgow.
Graham, Morton & Co.	Leeds.
Handyside & Co., Ltd.	Derby.
Harper, Louis	Aberdeen.
Hanna, Donald & Wilson	Paisley.
Heenan & Froude, Ltd.	Newton Heath, Manchester.
Hemingways, Ltd.	Middlesbrough.
Hill & Smith,	Brierley Hill, Staffordshire.
Horseley Co., Ltd.	Tipton, Staffordshire.
Isca Foundry and Engineering Co.	Newport, Mon.
Lysaght, J., Ltd.	St. Vincent Works, Bristol.
Maclellan, P. & W., Co.	Clutha Works, Glasgow.
Main, A. & J., & Co., Ltd.	49, Cannon Street, E.C.
Measures Brothers, Ltd.	53B, Southwark Street, S.E.
Mechan & Sons	Scotstoun Iron Works, Glasgow.
Morton, F., & Co., Ltd.	Garston, Liverpool.
Patent Shaft and Axletree Co., Ltd	Wednesbury.
Rowell, D., & Co.	31, Old Queen Street, Westminster, S.W.
Sands, Geo. & Son	Nottingham.
Smith, A. & W., & Co., Ltd.	Eglinton Engine Works, Glasgow.
CEMENT.	
Barron, F. C., & Co., Ltd.	6, Lloyds' Avenue, E.C.
Cement Users' Association.	28, Victoria Street, Westminster, S.W.
Earle, G. & T., Ltd.	Wilmington, Hull.
East Anglian Cement Co.	Shepreth, Cambs.
Greaves, Bull & Lakin, Ltd.	Harbury, Leamington.
Kaye & Co., Ltd.	Southam Works, Rugby.
Nelson, C., & Co., Ltd.	Stockton, Rugby.
Rugby Portland Cement Co.	Rugby.

Salter & Co., George	West Bromwich (cement testing apparatus).
Wouldham Cement Co. (1900),Ltd.	35, Great St. Helens, E.C.
West Kent Portland Cement Co.	Burham, near Rochester.

CONCRETE MIXERS.

Jessop & Appleby Brothers (Leicester and London), Ltd.	Leicester and London.
Mason Brothers	Brandon Street, Leicester.
Wilson, John H., & Co., Ltd.	Sandhills, Liverpool.
Waller, Geo., & Co.	165, Queen Victoria Street, E.C.

CONTRACTORS' PLANT.

Bagnall, W. G., Ltd.	Castle Engine Works, Stafford.
Blacknell, H.	Fleet, Hants.
Blackstone & Co., Ltd.	Stamford.
Bolling & Lowe	2, Laurence Pountney Hill, E.C.
Brown, E. H.	Kingsbury Works, Ball's Pond, N.
Gwynne & Co.	Brooke Street Works, Holborn, E.C.
Hadfield's Steel Foundry Co., Ltd.	Hecla Works, Sheffield.
Hardy Patent Pick Co., Ltd.	Sheffield.
Henderson, J. M., & Co.	King Street Works, Aberdeen.
Hudson, R.	Gildersome Foundry, Leeds.
Isca Foundry and Engineering Co.	Newport, Mon.
Jessop & Appleby Brothers., Ltd.	Leicester.
McLachlan & Co.	Darlington.
Marsden, H. R.	Soho Foundry, Leeds.
Phillips, C. D.	Emlyn Works, Newport, Mon.
Pulsometer Engineering Co., Ltd.	63, Queen Victoria Street, E.C.
Richards, R., & Co.	Upper Ground Street, S.E.
Smedley Brothers, Ltd.	Belper.
Sykes, H., Ltd.	66, Bankside, S.E.
Waller, Geo., & Co.	145, Queen Victoria Street, E.C.
Wells, A. C., & Co.	101, Midland Road, St. Pancras, London.
Wilson, J. H., & Co., Ltd.	Sandhills, Liverpool.

EXCAVATORS.

Chaplin, A., & Co.	Govan, Glasgow.
Coles, H. J.	London Crane Works, Derby.
Fleming & Ferguson, Ltd.	Paisley, N.B.
Jessop & Appleby, Brothers, Ltd.	Leicester.

Lobnitz & Co., Ltd.	Renfrew, Scotland.
Priestman Brothers, Ltd.	Holderness Foundry, Hull.
Rose, Downs & Thompson, Ltd.	Hull.
Ruston, Proctor & Co., Ltd.	Lincoln.
Schram, Richard, & Co.	Cannon Street House, E.C.
Whitaker Brothers, Ltd.	Horsforth, Leeds.
Wilson, J. H., & Co., Ltd.	Sandhills, Liverpool.

FENCING.

Bayliss, Jones & Bayliss, Ltd.	Victoria Works, Wolverhampton.
Hayward Brothers, & Eckstein, Ltd.	187, 189, 191, 193, Union Street, Borough, S.E.
Hill & Smith	Brierley Hill, Staffs.
Main, A. J., & Co., Ltd.	49, Cannon Street, E.C.
Morton, F., & Co., Ltd.	Garston, Liverpool.
Rowell, D., & Co.	31, Old Queen Street, S.W.
Smith, G. B., & Co.	Saracen Street, Glasgow.

GULLIES (STREET).

Albion Clay Co., Ltd.	Woodville, Burton-on-Trent.
Ames Crosta Sanitary Engineering Co.	City Chambers, South Parade, Nottingham.
Doulton & Co.	Lambeth Potteries, Lambeth, S.E.

IRON BUILDINGS.

Arrol, Sir W., & Co., Ltd.	Dalmarnock Ironworks, Glasgow.
Arrol's Bridge and Roof Co., Ltd.	Germiston Works, Glasgow.
Ash, J., & Son	Rea Street South, Birmingham.
Barrowfield Ironworks, Ltd.	100, Fordneuk Street, Glasgow.
Baldwins, Ltd.	5, Fenchurch Street, E.C.
Boulton & Paul, Ltd.	Norwich.
Clyde Structural Iron Co., Ltd.	Clydeside Works, Glasgow.
Croggan & Co., Ltd.	16, Upper Thames Street, London, E.C.
Dixon, I., & Co.	15, Cockspur Street, S.W.
Dalziel Bridge and Roof Building Co., Ltd.	Motherwell, near Glasgow.
De Bergue & Co., Ltd.	Strangeways, Manchester.
Finch, E., & Co., Ltd.	Chepstow.
Gimgon & Co., Ltd.	Leicester.
Graham, Morton & Co.	Leeds.
Hemingways, Ltd.	Middlesbrough.
Hill & Smith	Brierley Hill, Staffordshire.
Lysaght, J., Ltd.	St. Vincent Works, Bristol.

Main, A. and J., & Co., Ltd.	77A, Queen Victoria Street, E.C.
Mechan & Sons,	Scotstoun Ironworks, Glasgow.
Morton, F., & Co., Ltd.	Garston, Liverpool.
Renshaw, W. R., & Co., Ltd.	Phoenix Works, Stoke-on-Trent.
Rowell, D., & Co.	31, Old Queen Street, S.W.
Sands, Geo., & Son	Nottingham.
Waller, Geo., & Co.	165, Queen Victoria Street, E.C.

Labels, Name Plates, etc.

Barns, N., & Son	Christopher Works, Chalton Street, N.W.
Grangemouth Iron Co., Ltd.	Falkirk.
Smith, J.	Royal Label Factory, Stratford-on-Avon.
Taylor, Taylor, & Hobson, Ltd.	Stoughton Street Works, Leicester.

Mortar Mills.

Mason Brothers	Brandon Street, Leicester.
Phillips, C. D.	Emlyn Works, Newport, Mon.
Smedley, Brothers, Ltd.	Belper.
Wootton Brothers	Coalville, Leicester.

Motor Vehicles.

Brooke, J. W., & Co., Ltd.	Adrian Works, Lowestoft.
Coulthard, T., & Co., Ltd.	Preston.
Lancashire Steam Motor Co.	Leyland.
Mann's Patent Steam Car and Wagon Co., Ltd.	Canning Works, Dewsbury, Leeds.
Musker, C. & A., Ltd.	Liverpool.
Savage Brothers	Kings Lynn.
Simpson & Bibby	Pomona Works, Cornbrook, Manchester.
Straker Steam Vehicle Co., Ltd.	9, Bush Lane, Cannon Street, E.C.
Thornycroft Steam Wagon Co., Ltd.	Chiswick and Basingstoke.
Yorkshire Patent Steam Wagon Co.	Leeds.

Motors (Electric).

Allen, W. H., Son & Co., Ltd.	Queen's Engineering Works, Bedford.
Becker, R., & Co.	53, City Road, E.C.
Beyer, Peacock & Co., Ltd.	Gorton Foundry, Manchester.
British Thomson-Houston Co., Ltd.	Rugby.

British Westinghouse Electric and Manufacturing Co., Ltd.	Norfolk Street, Strand, W.C.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Crompton & Co., Ltd.	Salisbury House, London Wall, E.C.
East Anglian Engineering Co., Ltd.	Stowmarket, Suffolk.
Easton & Co., Ltd.	Erith, Kent.
Eidson & Swan United Electric Light Company, Ltd.	Ediswan Buildings, Queen Street, Cheapside, E.C.
Electric and Ordnance Accessories Co.	Stellite Works, Birmingham.
Electrical Co., Ltd.	122 and 124, Charing Cross Road, W.C.
Ferranti, Ltd.	Hollinwood, Lancs.
Greenwood & Batley, Ltd.	Leeds.
Hartnell, Wilson, & Co., Ltd.	Kirkstall Road, Leeds.
India Rubber, Gutta Percha, and Telegraph Works Co., Ltd.	Silvertown, Essex.
Jackson, P. R., & Co., Ltd.	Salford Rolling Mills, Manchester.
Johnson & Phillips	14, Union Court, E.C.
Laurence, Scott & Co., Ltd.	Norwich.
Mather & Platt, Ltd.	Manchester.
Musker, C. & A., Ltd.	Liverpool.
Newton Electrical Works, Ltd.	Taunton.
Parsons, C. A., & Co.	Newcastle-on-Tyne.
Paterson, Cooper & Co., Ltd.	Patella Works, Paisley.
Peebles, Bruce, & Co., Ltd.	Tay Works, Edinburgh.
Rhodes Electrical Manufacturing Co.	71, Bishopsgate Street Within, E.C.
Scott, Ernest, & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
Sturtevant Engineering Co., Ltd.	147, Queen Victoria Street, E.C.
Sunderland Forge and Engineering Co., Ltd.	Pallion, Sunderland.
Tangye Tool and Electric Co., Ltd.	Oxford Works, Birmingham.
Turner, Atherton & Co.	Manchester,
Veritys	31 and 32, King Street, W.C.

PAVEMENT LIGHTS.

Hayward Brothers, & Echstein, Ltd.	187, 189, 191 and 193, Union Street, Borough, London, S.E.
St. Pancras Ironwork Co., Ltd.	171, St. Pancras Road, London, N.W.

PICKS, SHOVELS, AND SPADES.

Hardy Patent Pick Co., Ltd.	Sheffield.

Hadfield's Steel Foundry Co., Ltd.	Hecla Works, Sheffield.
Rogerson, John, & Co., Ltd.	Wolsingham, R.S.O., Co. Durham.

QUARRYING MACHINERY.

Bullivant & Co.	20, Mark Lane, E.C.
Henderson, J. M.; & Co.	King Street Engineering Works, Aberdeen, Scotland.

ROAD ROLLERS, SCARIFIERS, TRACTION ENGINES, ETC.

Aveling & Porter	Rochester.
Burrell, C., & Sons, Ltd.	Thetford, Norfolk.
Clayton, Shuttleworth, & Co., Ltd.	Lincoln.
Dodman, A., & Co., Ltd.	Highgate Works, King's Lynn.
Eddison & De Mattos, Ltd.	Dorchester, Dorset.
Garrett, R., & Sons, Ltd.	Leiston Works, Suffolk.
Green, Thomas, & Son, Ltd.	Smithfield Iron Works, Leeds.
Fowler, J., & Co., Leeds, Ltd.	Leeds, and 6, Lombard Street, E.C.
Lambert, William, & Co.	Horsmonden, Kent.
McLaren, J., & H.	Midland Engine Works, Leeds.
Manlove, Alliott, & Co., Ltd.	Nottingham, London, Manchester and Glasgow.
Marshall, Sons, & Co., Ltd.	Gainsborough.
Oxfordshire Steam Ploughing Co.	Cowley, Oxford.
Phillips, C. D.	Emlyn Works and Foundry, Newport, Mon.
Ransomes, Sims & Jefferies	Ipswich.
Ruston Proctor & Co.	Lincoln.
Rutty, Geo., & Co.	Bromley-by-Bow, London, E.

ROAD SCRAPERS, HORSE BROOMS, DUST AND WATER CARTS AND VANS, AND GENERAL SCAVENGING PLANT.

Baker, T., & Sons	Compton, Berks.
Burrows & Co., Ltd.	Banbury, Oxon.
Bird, F., & Co.	11, Great Castle Street, Regent Street, London, W.
Bristol Wagon & Carriage Works Co., Ltd.	Lawrence Hill, Bristol.
Chalmers, & Co.	Redhill, Surrey.
Corin, & Son, J. M. B.	Engineers and Founders, Penzance.
Glover, Wm., & Sons	Warwick.
Phœnix Engineering Co., Ltd.	Chard.
Savage, Brothers	King's Lynn.

The Nevill Engineering Co., Ltd.	Piston Foundry, Worcester.
Vipan & Headley	Church Gate Works, Leicester.
Waller, Geo., & Co.	165, Queen Victoria Street, E.C.

STONE (ARTIFICIAL).

Abell & Cammell	Hartshill Concrete Works, near Atherstone.
Adamant Stone & Paving Co., Ltd.	Palace Chambers, 9, Bridge Street, Westminster, S.W.
Atlas Stone Co.	Cambridge.
Barrow Cement & Flag Co.	Devonshire Road, Barrow-in-Furness.
Ellis, J., & Sons	1, St. Martins, Leicester.
Empire Indurated Stone Co.	Waterloo Street, Leicester.
Excelsior Patent Stone Co.	Finedon Sidings, Midland Rail, Northamptonshire.
Hard York Stone Co.	Halifax.
Imperial Stone Co., Ltd.	East Greenwich, S.E.
Old Radnor Trading Co., Ltd.	Kington, Herefordshire.
Patent Victoria Stone Co., Ltd.	10–13, Hamilton House, Bishopsgate Street Without, E.C.
Patent Indurated Stone Co., Ltd.	Millwall, London, E.
Preston Granite Concrete Co., Ltd.	Preston Docks, Lancashire.
Tytherington Stone Co.	Tytherington, Falfield, R.S.O., Glos.

STONE AND FLAG MACHINERY.

Berry, H., & Co., Ltd.	Croydon Works, Hunslet, Leeds.
Fielding & Platt, Ltd.	Gloucester, and 118, Queen Victoria Street, E.C.
Musker, C. & A., Ltd.	Liverpool.

STONEBREAKERS.

Askam Brothers, & Wilson, Ltd.	Sheffield.
Baker Blower Engineering Co.	Stanley Works, Sheffield.
Baxter, W. H., Ltd.	Leeds.
Broadbent, R., & Son	Stalybridge.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, E.C.
Goodwin, Barsby, & Co.	Engineers, Leicester.
Hadfield's Steel Foundry Co., Ltd.	Hecla Works, Sheffield.
Hall, J. S.	Midland Ironworks, Newark-on-Trent.
Jessop, W., & Sons, Ltd.	Sheffield.

Marsden, H. R.	Soho Foundry, Leeds.
Mason Brothers	Brandon Street, Leicester.
Pegg, Samuel, & Son	Engineers, Leicester.
Robey & Co., Ltd.	Lincoln.
Whitaker Brothers, Ltd.	Horsforth, Leeds.

STONE, GRANITE, SLAG, ROAD-METALLING.

Bristow, T., & Brothers	Speen, Princes Risborough, Bucks.
British Paving & Granite Co.	16, Great George Street, Westminster, S.W.,
Brundrit & Co., Ltd.	10, Dale Street, Liverpool.
Caithness Flagstone Co.	Thurso.
Charnwood Granite Co.	Charnwood Quarries, near Loughborough.
Clee Hill Granite Co.	Ludlow, Salop.
Clee Hill Dhu Stone Co.	Ludlow, Salop.
Cliffe Hill Granite Co., Ltd.	Markfield, near Leicester.
Croft Granite Co., Ltd.	Croft, near Leicester.
Darbishires, Ltd.	Granite Quarries, Penmaenmawr.
Enderby & Stoney Stanton Co., Ltd.	Narboro', near Leicester.
Field & Mackay	Titherstone Quarries, Clee Hill, Ludlow.
Freakley, J., & Co., Ltd.	Coneygre Slag Works, Dudley Port, Tipton.
Forest Rock Granite Co., Ltd.	Whitwick, near Leicester.
Griffiths, W., & Co.	41, Hamilton House, Bishopsgate Street Without, E.C.
Groby Granite Co., Ltd.	Groby, near Leicester.
Hopton-Wood Stone Co.	Wirksworth, Derbyshire.
Inverawe Granite Quarries, Ltd.	212, West George Street, Glasgow.
London Basalt Stone Co., Ltd.	45, Parliament Street, Westminster, S.W.
Lough South Quarry Co.,	Bury Road, Rawtenstall, Manter.
Mountsorrel Granite Co.	Mountsorrel, near Loughborough.
Murray & Co., W. H.	47 and 48, King William Street, E.C.
Old Radnor Trading Co., Ltd.	Kington, Herefordshire.
Ord & Maddison, Ltd.	Darlington.
Pwllheli Granite Co.	78, High Street, Runcorn.
Road Maintenance Supply Co.	Gravesend.
Runnals, J., & Sons	Penlee Stone Quarries, Penzance.
Rowley Regis Granite Quarries, Ltd.	Rowley Regis, near Birmingham.

APPENDIX TO LECTURE I

Shap Granite Co., Ltd.	Shap, Westmoreland.
The St. Keverne Stone Co.	Porthonstock, St. Keverne, Cornwall, R.S.O.
United Newry Granite Co., Ltd.	55, Market Street, Manchester.
United Granite Quarries	Pike's Wharf, 45, Wells Street, Camberwell, S.E.
Wainwright, John, & Co.	Shepton Mallet.
Wigan Coal & Iron Co., Ltd.	Kirkless, Wigan, Lancashire.
Woolston, J.	Stamford.

Tar Paving.

Bradshaw & Co.	52, Queen Victoria Street, E.C.
Chittenden, Lake, & Co.	Allington, Maidstone.
Hobman, A. C. W., & Co.	Cliftonville, South Bermondsey, S.E.

Wood Paving and Flooring.

Acme Wood Flooring Co.	Gainsborough Road, Victoria Park, London, N.E.
Alcott, Edward	65 and 67, Millbank Street, Westminster, S.W.
Armstrong, Addison & Co.	Sunderland.
Millars, Karri & Jarrah Forests, Ltd.	72, Bishopsgate Street Within, E.C.
Peters, Bartsch, & Co.	Derby.
Jarrahdale Jarrah Forests and Railways, Ltd.	1, Fenchurch Avenue, London, E.C.
The Sanitary Block and Tile Pavement Co.	17, Victoria Street, Westminster, S.W.
Prismatic Wood Paving Co. (Agent Vernon Parker)	20, Victoria Street, Westminster, S.W.

LECTURE II

SEWERAGE and MAIN DRAINAGE—SEWAGE DISPOSAL—DISPOSAL OF DOMESTIC and TRADE REFUSE

Sewerage and Main Drainage

I PROCEED now to notice another important branch of our subject, viz. that of "Sewerage and Main Drainage," and in this connexion the briefest retrospect will reveal to us a very marked degree of progress made during the past half century. The rapid growth of town population, the increased knowledge of hygienic laws, and the general sanitary reformation of the Victorian era have long displaced the old culverted watercourse and the rubble stone drain for the properly designed brick, iron, or glazed stoneware pipe sewer. There has also been a general and energetic crusade against the once popular "cesspool," and the city, town, and village alike have striven to secure a main drainage system that shall in no way fall short of the most exacting requirements of present-day sanitation. The details of design and workmanship have received the closest attention of those whose duties have cast upon them the responsibilities appertaining to the execution of such works, and during the past few decades certain well-considered general principles have been established as the outcome of a judicious combination of theory and practice. For example, such questions as the form and size of cross section of sewers, the directness of line and trueness of invert, smoothness of bore, velocity of flow, and amount of discharge are matters which have called for the fullest consideration, in order that the various parts of the system under design may be suitably approximated to the work they will be called on to perform.

In towns situated on sloping ground a well-considered arrangement of "intercepting sewers" forms part of the design, so that the heavy rainfalls of the upper parts of the district may not flood the lower, and that the sewer gases from the lower may not rise, to the detriment of the upper areas.

Schemes of main drainage are now designed either upon what is usually known as the "combined" system or on the "separate" system. In the former both sewage and storm water are provided for in one and the same sewer, whilst in the latter as much rainfall as possible is excluded from the sewers proper, and conveyed away by means of a distinct system of storm-water drains to some natural outlet.

Throughout Great Britain at the present day a strict conservancy is very properly maintained over all rivers and tributary streams, necessitating the greatest care in the laying down of a system of sewers, in order that there may be no pollution of watercourses arising therefrom. The choice of a system will therefore be largely influenced by these considerations, and also by the nature of the proposed treatment of the sewage proper at the outfall works.

The amount of rainfall to be admitted will very materially affect the sizes of the sewers to be provided, as well as the question of the disposal of the sewage at the outfall works. In this country one inch of rain per hour occurs at distant intervals only, such as during severe storms, so that a provision for that amount should prove sufficient. Greater falls have of course been recorded, but any further increase of the size of the sewers would reduce their efficiency under ordinary conditions. In the Metropolitan sewers provision was made for only ·01 inch of rainfall per hour, in addition to an allowance of five cubic feet of sewage per head of the population per day. When providing a new system of sewers for the city of Edinburgh the combined estimate of sewage and rainfall was forty-two gallons per head per day, one half to pass off in eight hours, the rainfall being taken at two inches.

In order to prevent deposit in sewers and drains, i.e. that they may be self-cleansing in their operation, the minimum and maximum velocities of flow and the needful inclinations to secure the same are interesting problems in hydraulics, which have received very careful and painstaking investigation. For sewers from 6 in. to 9 in. diameter, experience has shown that a minimum velocity of 3 feet per second should obtain, for 12 in. to 24 in. diameters, a velocity of 2 ft. 6 in., and for larger sewers 2 ft. per second. On the other hand, excessive velocities are to be avoided, and to prevent damage to the sewers the maximum velocity should be limited to from 4½ ft. to 6 ft. per second.

The construction of main drainage works to serve any large population usually involves engineering features of considerable difficulty and complication. Such works have been carried to a successful completion by the majority of towns throughout Great Britain, and have necessitated the expenditure of very large sums of money for their satisfactory execution. The carrying of large outfall sewers considerable distances from the boundaries of populated centres (such for example, as the northern and southern outfalls, discharging at Barking and Crossness, the sites of the outfall works of the Metropolitan main drainage) involves the crossing either over or under of canals, roadways, lines of railway, and many other existing works. Such undertakings also occasionally involve the tunnelling of rivers or crossing same by means of inverted siphons laid in the bed, the construction of tidal outlets, and works for the storage, pumping, filtration or other treatment of the sewage at the outfall end. As an example of this class of work, the Metropolitan main drainage was a scheme of great magnitude, costing many millions sterling, commenced in 1859, and carried out during the succeeding six years, but since considerably extended in order to meet the growing needs of now near upon six millions of people.

The system adopted was designed by the late Sir Joseph Bazalgette, who proposed the building of large intercepting sewers on each side of the Thames, for the purpose of intercepting all sewers then discharging into the River, and carrying the sewage forward to Barking and Crossness, on the north and south banks respectively. On the north of the River are three intercepting sewers, known as the high, middle and low level, of a total length of about 30¾ miles, draining an area of some 50 square miles. These sewers range in size from 4 ft. barrel up to 9 ft. 6 ins. by 12 ft. The sewage from the high and middle levels runs to Barking by

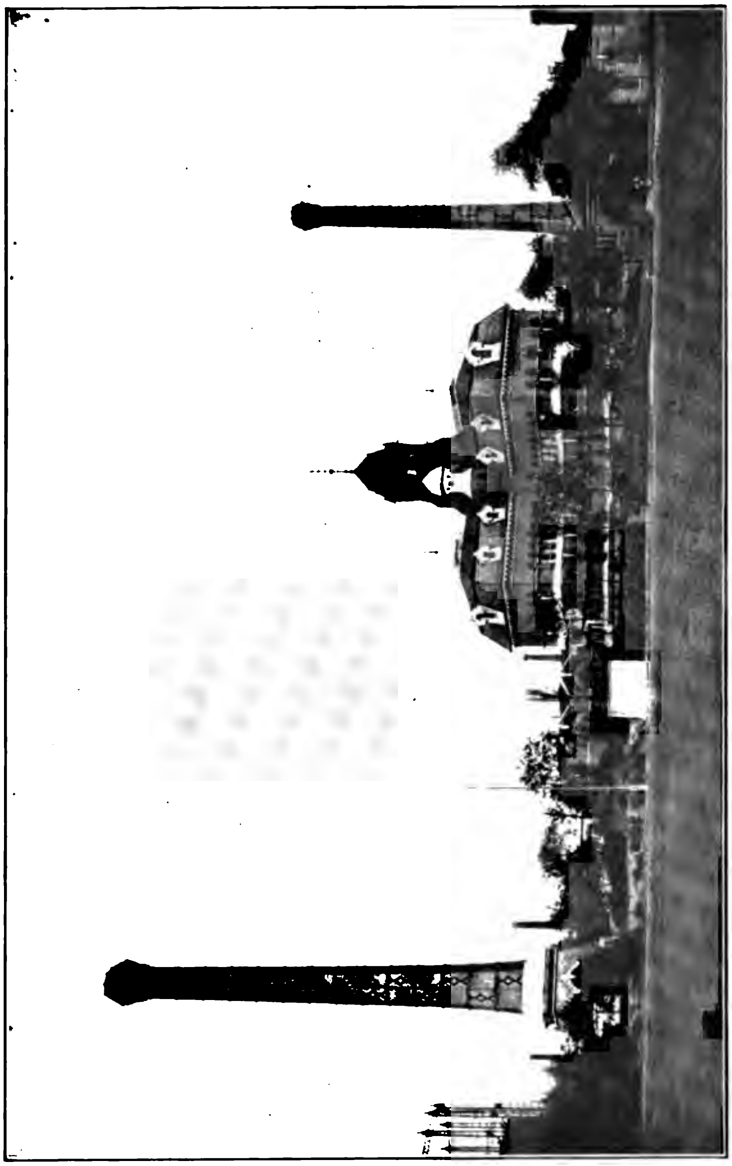


FIG. 2.—LONDON MAIN DRAINAGE—ABBEY MILLS PUMPING STATION. MAIN ENGINE HOUSE.

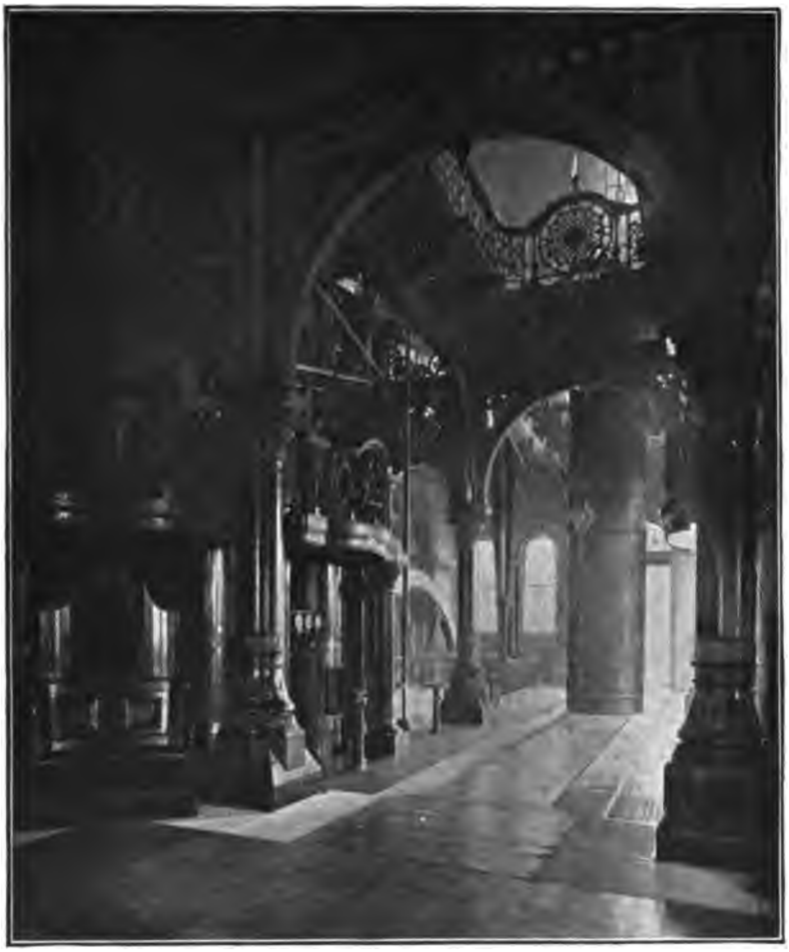


FIG. 3.—LONDON MAIN DRAINAGE—ABBEY MILLS PUMPING STATION. VIEW OF MAIN ENGINE HOUSE.

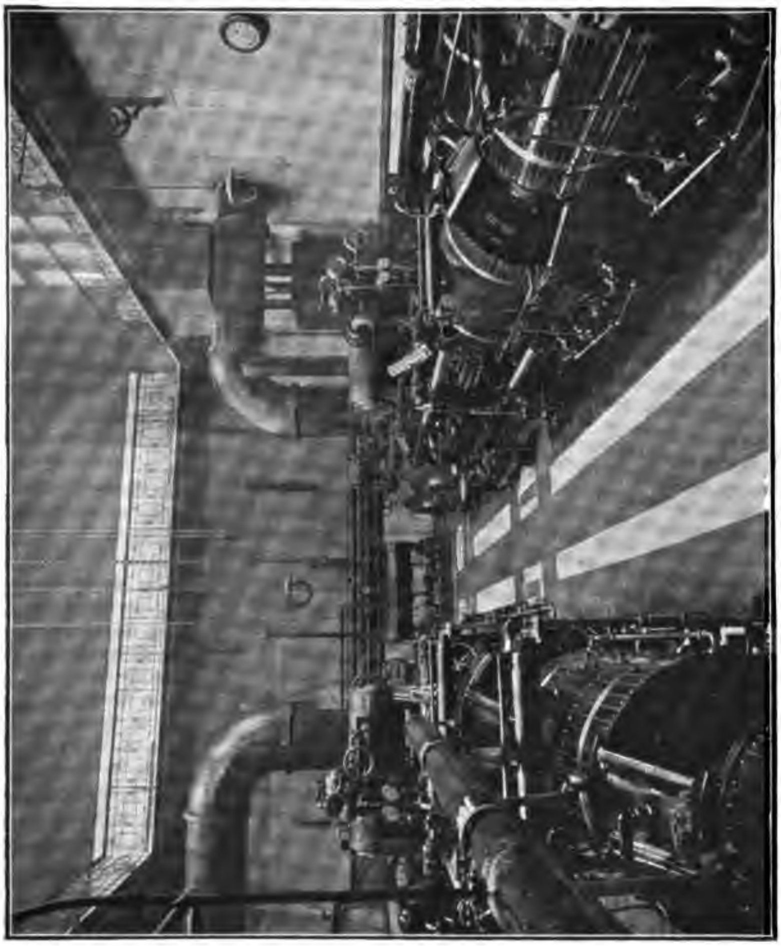


FIG. 4.—LONDON MAIN DRAINAGE. "WORTHINGTON" ENGINE HOUSE IN ABBEY MILLS PUMPING STATION.

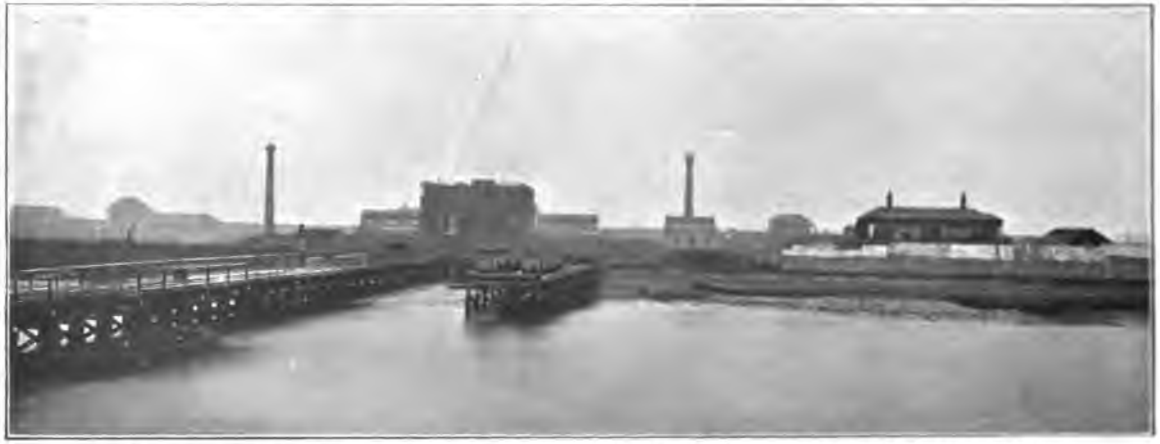


FIG. 5.—LONDON MAIN DRAINAGE. BARKING OUTFALL, SHOWING JETTY, SLUDGE TANKS, ETC.

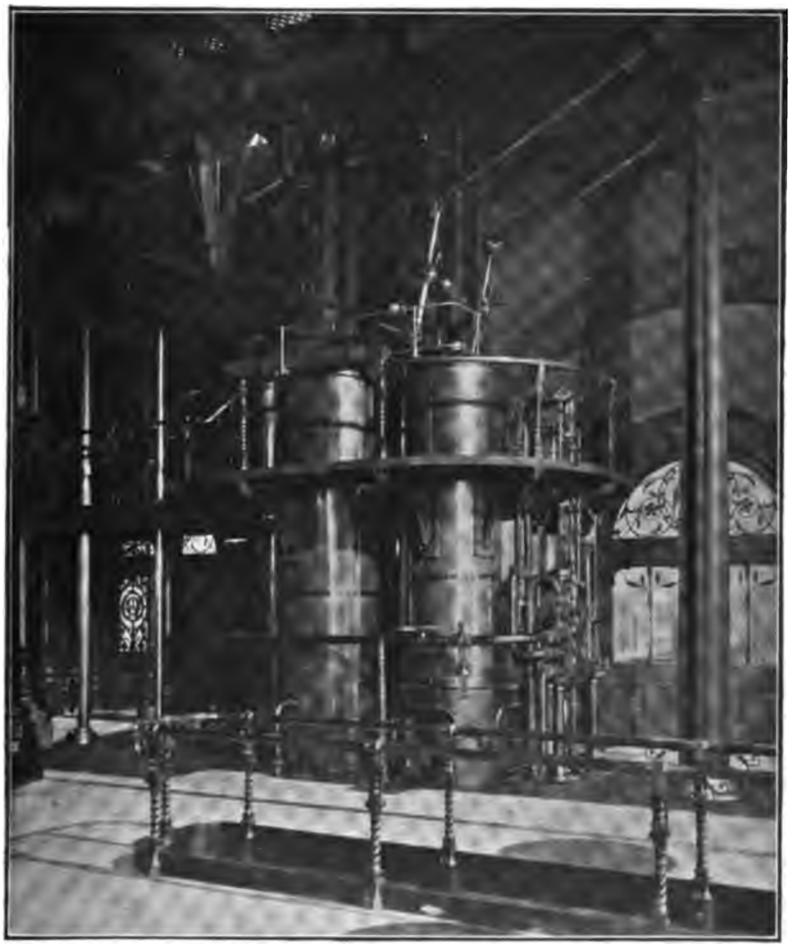


FIG. 6.—LONDON MAIN DRAINAGE. CROSSNESS PUMPING STATION, SHOWING BEAM ENGINES.

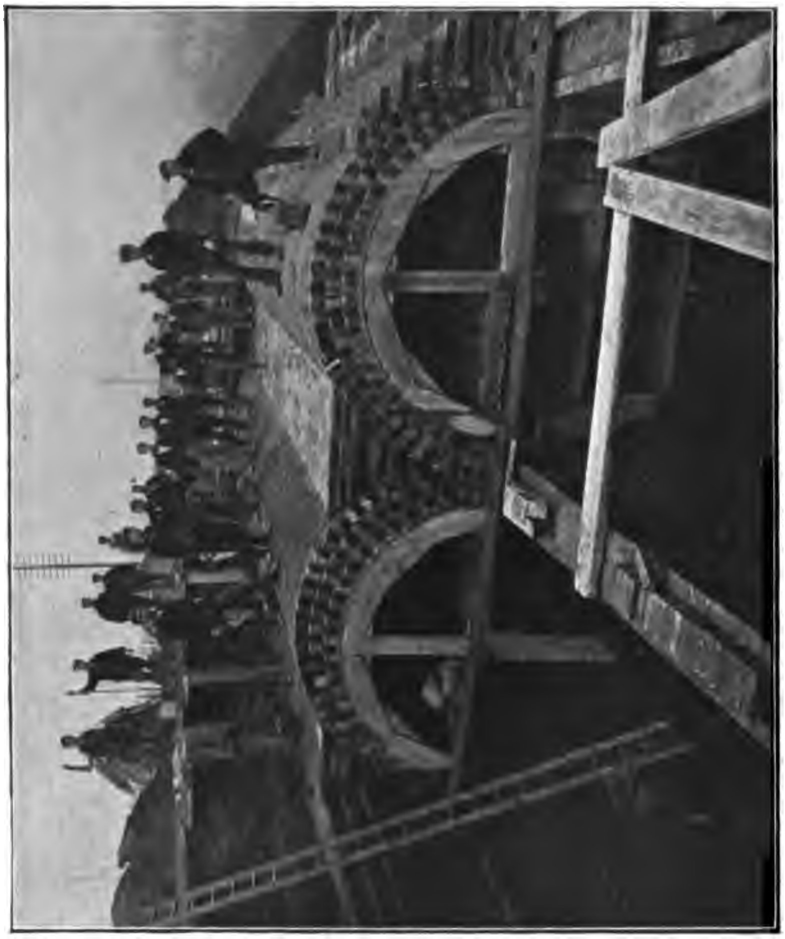


FIG. 7.—LONDON MAIN DRAINAGE. NEW NORTHERN OUTFALL SEWERS, 9 FT. IN DIAMETER.

gravitation, but that of the low level is pumped at the Western Pumping Station (Pimlico), and again at the Abbey Mills Pumping Station (West Ham). (See Figs. 1 to 4.) From thence it flows to Barking by gravitation (Fig. 5).

There are also three main intercepting sewers on the south side of the River, viz: the high level, the Effra, and the low level; the first two run to Crossness by gravitation, and the latter is pumped at Deptford. These three sewers have an aggregate length of 26 miles, and drain an area of about 30½ square miles. Their sizes vary between 4 ft. by 2 ft. 8 ins. and 10 ft. 6 ins. by 10 ft. 6 ins. All the sewage arriving at the Crossness Station has to be pumped (Fig. 6).

In addition to the foregoing, there are, of course, a large number of branch main sewers under the control of the London County Council, bringing the sewage from the various districts into these outfall sewers (Fig. 7). And again, there are a still larger number of smaller local sewers under the control of the Borough Councils, bringing the drainage from the houses, streets, etc., into the sewers of the County (Fig. 8).

These different classes of sewers are not designed to carry off excessive rainfalls; and should such occur at the same time as high tide in the River, the outlets from the storm water overflows become closed by the water in the River. To reduce flooding, therefore, pumping stations have been constructed on some of the storm relief sewers, for the purpose of pumping the rain water into the river, when at times of high water it cannot flow in by gravitation. Such stations have been provided at Pimlico (the Western Pumping Station), Abbey Mills, North Woolwich, Deptford, Crossness, Heathwall (Nine Elms Lane), Lot's Road, Chelsea, King's Scholars' Pond, and the Isle of Dogs. These several stations are capable of raising 632,424 gallons of sewage and storm water per minute, through varying lifts of from 14½ ft. up to 70 ft.

Of these pumping stations, that at Lot's Road (Figs. 9, 10 and 11) is the most recent, and was opened in February of this year (1904), for the purpose of dealing with local floodings at times of heavy rainfall on the Counter's Creek Sewer at Chelsea. In order to cope with storms of less than the maximum force without waste of power, the pumping machinery has been installed in eight units, each complete in itself, and consists of centrifugal pumps driven direct by ropes from gas engines. The four pumps controlling the rise of water in the Counter's Creek Sewer have suction and discharge branches 32 ins. in diameter and are each capable of delivering 3,000 cubic feet of water per minute; whilst the four pumps emptying the low level sewer have branches 23 ins. in diameter, and are each equal to a discharge of 1,500 cubic feet per minute.

The pumps were supplied and erected by Messrs Easton & Co., Ltd., at a cost of about £6,100, and the engines by Messrs. Crossley Bros., Ltd., at a cost of about £10,300. The total cost of providing this station, including the acquisition of the site, erection of the buildings, provision of machinery, etc., has been about £82,000.

Substantial progress has been made during late years in the production of a great variety of improved materials and special apparatus and plant, as now employed to great advantage in connexion with all main-drainage and sewer-

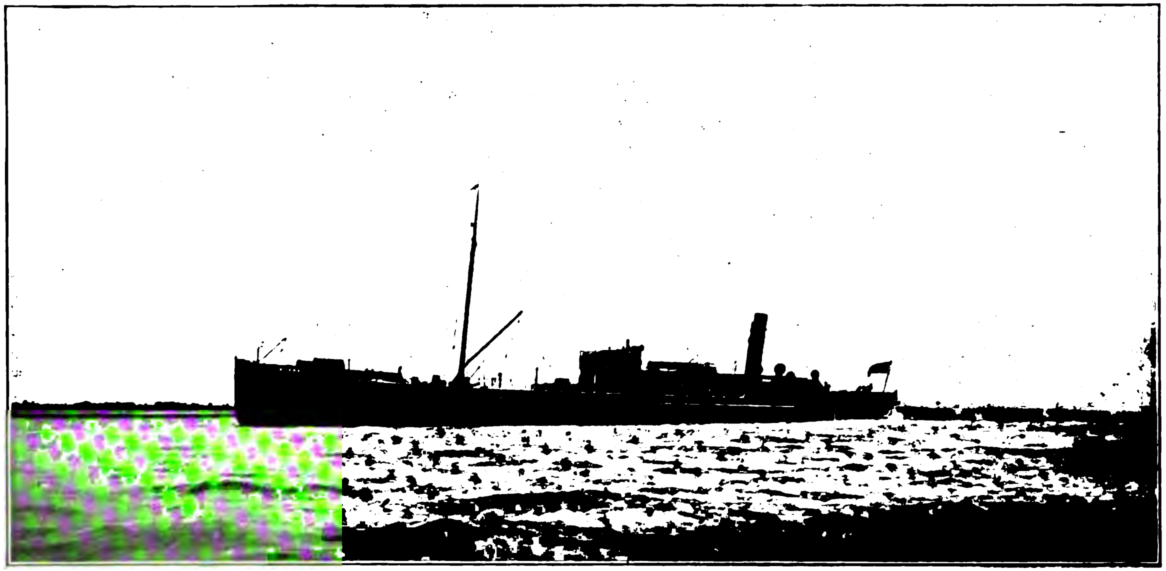


FIG. 8.—LONDON MAIN DRAINAGE. SLUDGE VESSEL SS. *BURNS*.

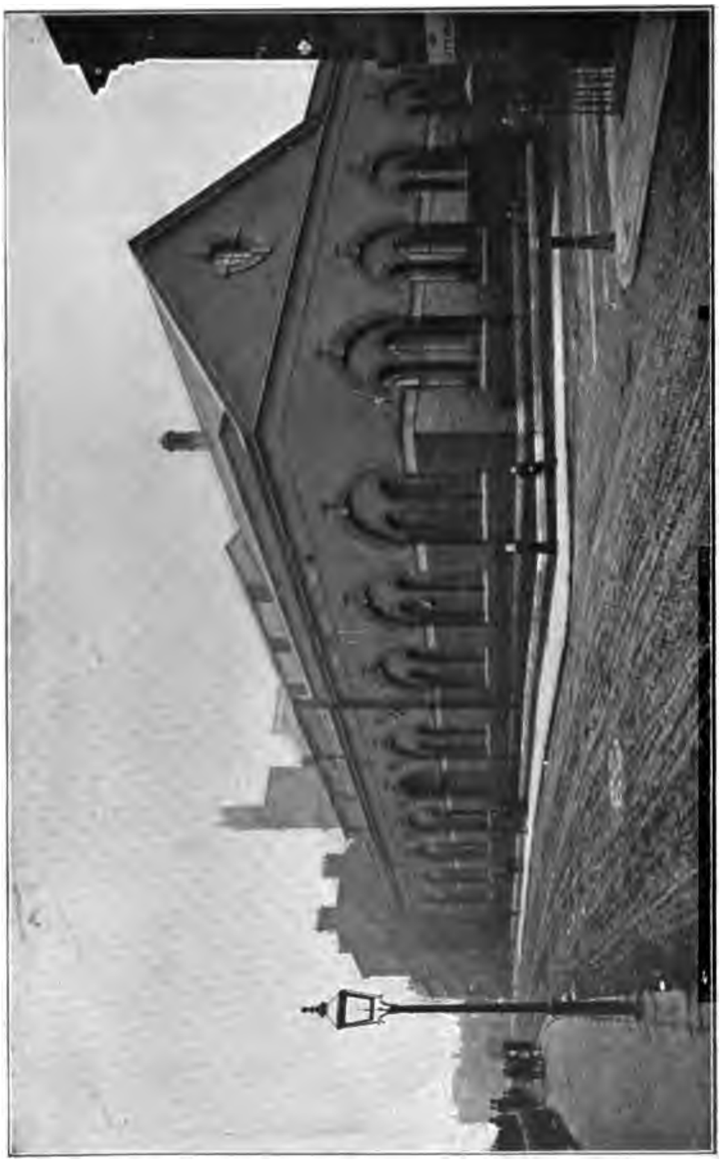


FIG. 9.—LONDON MAIN DRAINAGE—LOT'S ROAD PUMPING STATION. ENGINE HOUSE.

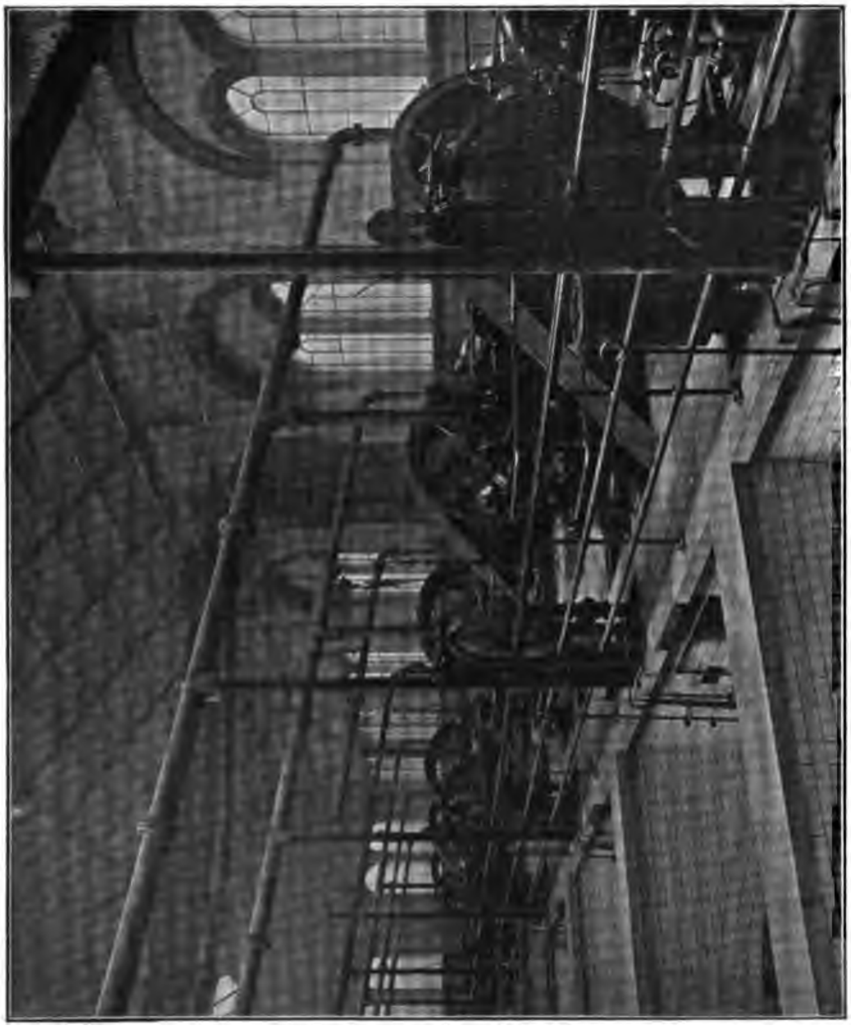


FIG. 10.—LONDON MAIN DRAINAGE. GAS ENGINES IN LOT'S ROAD PUMPING STATION.

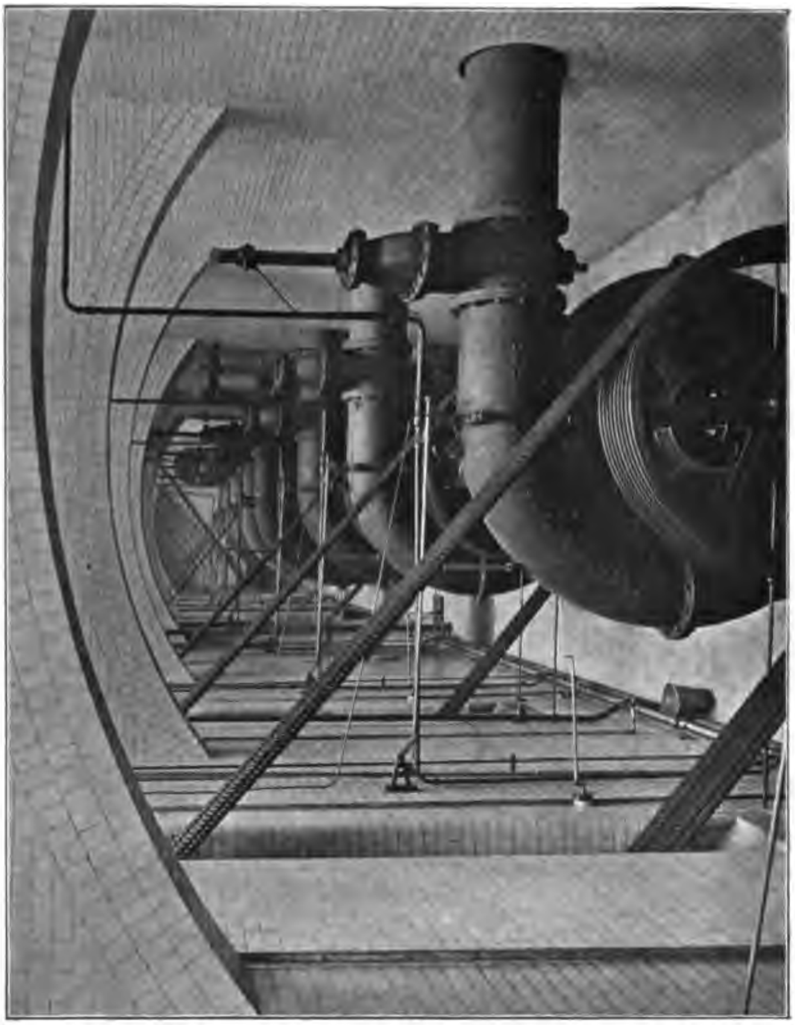


FIG. 11.—LONDON MAIN DRAINAGE. CENTRIFUGAL PUMPS IN LOT'S ROAD PUMPING STATION.

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age work. The use of unglazed earthenware and fireclay pipes has long given place to the much stronger and in all ways superior salt-glazed stoneware pipe, now made with various improved designs of water- and gas-tight joints. Of these may specially be mentioned Stanford's joint, Button's "secure" joint, Jenning's "double seal," Doulton's "self-adjusting" joint, Archer's patent, Hassall's "safety" pipe joint, Parker's "safety" pipe joint, Green's "true-invert" pipe, the "Paragon" pipe, the "Loco" drain joint, the Ames and Crosta pipe joint, Sykes' new patent joint, and Brown's "hydrotite" joint, all illustrated in Fig. 12.

Concrete tubes for main drainage purposes have also been successfully employed for some years past, and of these we have the "rock concrete" pipes of Messrs. Sharp, Jones and Co., Parkstone, Dorset; the "silicated stone pipes" manufactured by the Imperial Stone Company; and the patent steel-ribbed concrete tubes made by Messrs. John Ellis & Sons, of Leicester. Strong Staffordshire blue clay or "iron-ware" pipes are manufactured by Messrs. Hamblet, of West Bromwich, which are of great durability, and may be laid at either great or shallow depths without concrete protection.

Figure 13 illustrates the application to sewers and water conduits of concrete and expanded metal, as manufactured by the New Expanded Metal Company, of West Hartlepool and Westminster.

Cast iron is now much more largely used in both sewerage and house-drainage work than formerly, and offers many advantages in this connexion. All joints can be securely lead caulked and tested to a high pressure, and the pipes are not liable to fracture, as in the case of stoneware-pipe drains. A great variety of traps, inspection chambers, gullies, pipes, bends, junctions, and other specials of good design, can now be obtained from a large number of different manufacturers. Fig. 14 shows a "lever-locked" cast-iron inspection chamber as supplied by the North British Plumbing Company, and Fig. 15 illustrates the application of an iron intercepting trap for house drainage, fixed in a brick manhole, and having a ventilating arm, inspection pipe, etc., with air-tight iron cover, as manufactured by Messrs. Walter Macfarlane & Co. of Glasgow. This firm also supplies every kind of iron fitting or appliance required in a complete system of house drainage. The castings are dipped in Dr. Angus Smith's solution, or treated with Macfarlane's improved glass enamel, which latter renders the interiors as smooth as glass, prevents rust, and is also a specially useful application for soil pipes.

In connexion with all main drainage works, a large amount of constructional ironwork is necessarily employed, such as sewer penstocks, valves, flaps, siphons, floating arms, sluices, etc., as manufactured by Messrs. F. Bird & Co., George Waller & Co., J. Stone & Co., Beck & Co., and other makers.

Bird's improved penstock for large size sewers is shown in Fig. 16. It is made to any desired size, and is worked by means of two racks and worms with spur gearing and counter-balance weights. Where convenient, these large penstocks are also fitted with hydraulic lifting gear, as shown in Fig. 17, which illustrates a penstock of this description made by Messrs. George Waller & Co.

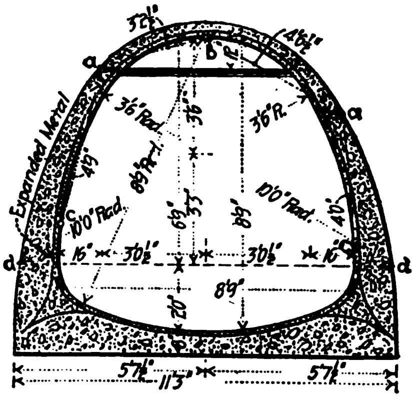


FIG. 12

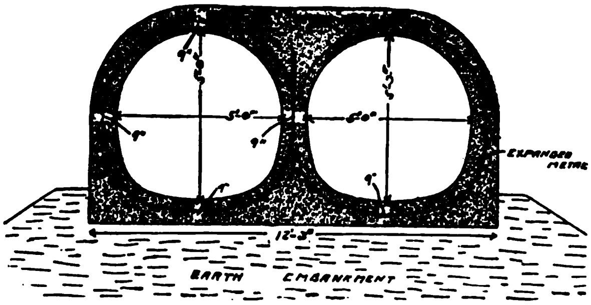


FIG. 13.—SEWER AND WATER CONDUITS (NEW EXPANDED METAL CO.).

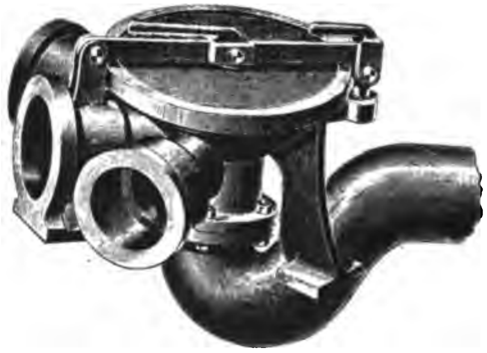


FIG. 14.—"LEVER LOCKED" CAST IRON INSPECTION CHAMBER (NORTH BRITISH PLUMBING CO.).

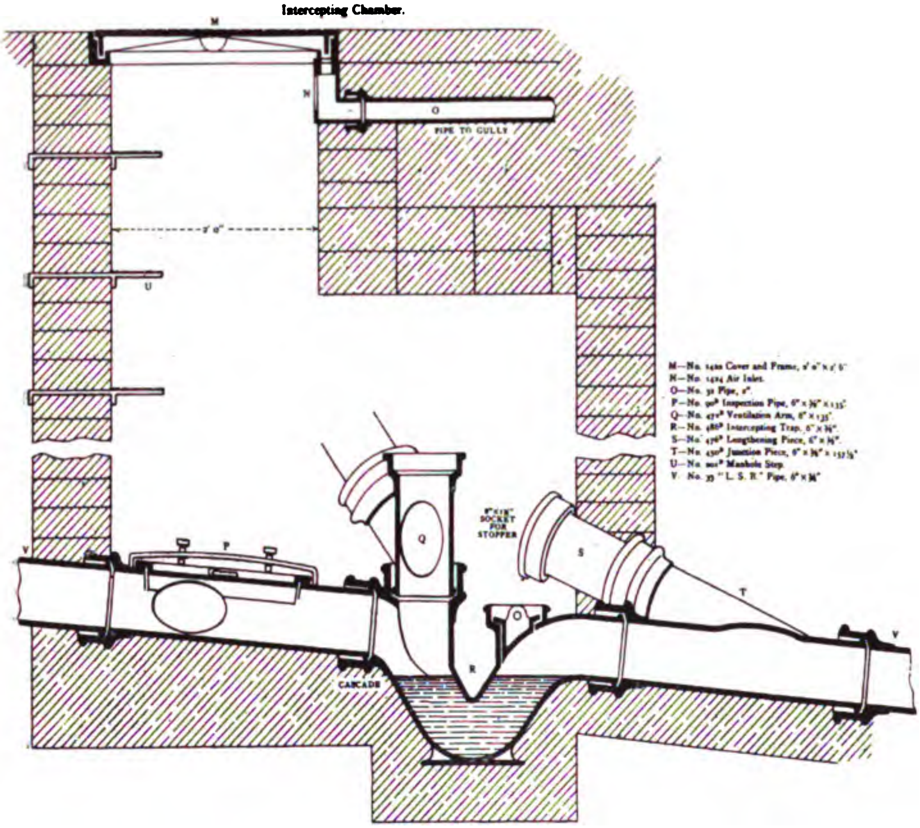

Intercepting Chamber.
M
N
O
PIPE TO GULLY
2' 0"
U
V
P
Q
6" × 18" SOCKET FOR STOPPER
S
T
R
V
CASCADE
M—No. 1420 Cover and Frame, 2' 0" × 2' 6"
N—No. 1424 Air Inlet.
O—No. 32 Pipe, 2".
P—No. 90^B Inspection Pipe, 6" × ⅜" × 13½"
Q—No. 472^B Ventilation Arm, 6" × 13½".
R—No. 486^B Intercepting Trap, 6" × ⅜".
S—No. 476^B Lengthening Piece, 6" × ⅜".
T—No. 430^B Junction Piece, 6" × ⅜" × 137½"
U—No. 201^B Manhole Step
V No. 33 "L. S. R." Pipe, 6" × ⅜"

FIG. 15.—IRON INTERCEPTING TRAP FOR HOUSE DRAINS (W. MACFARLANE & CO.).

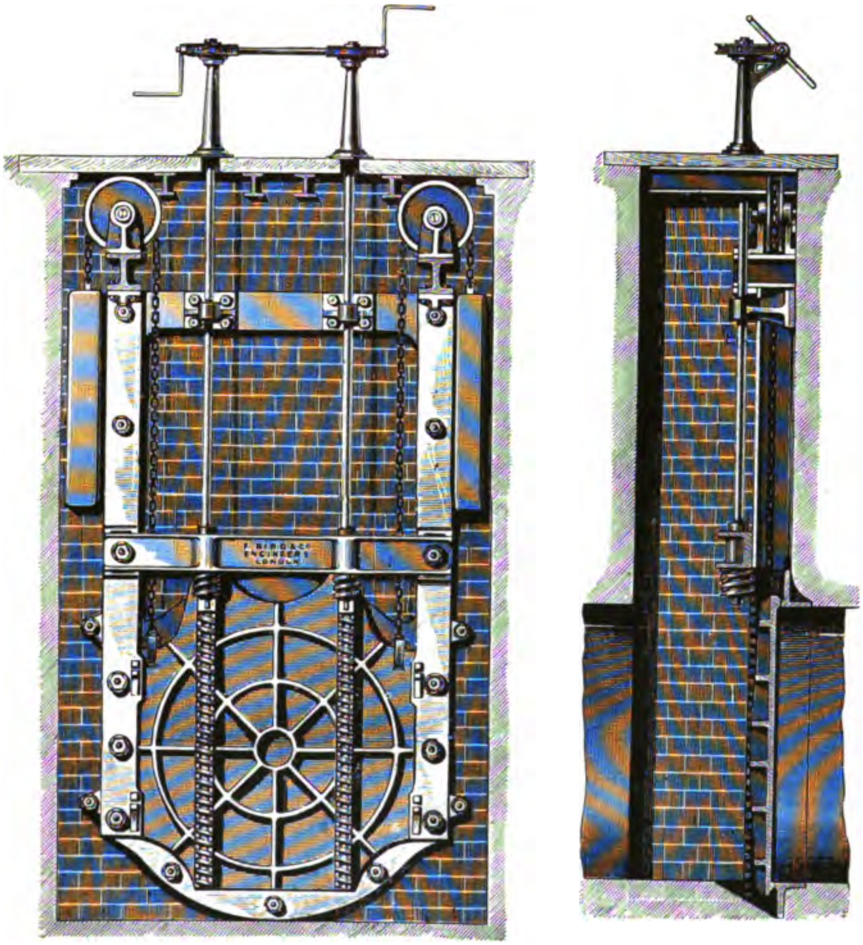


FIG. 16.—BIRD'S IMPROVED PENSTOCK (FREDERICK BIRD & CO.).

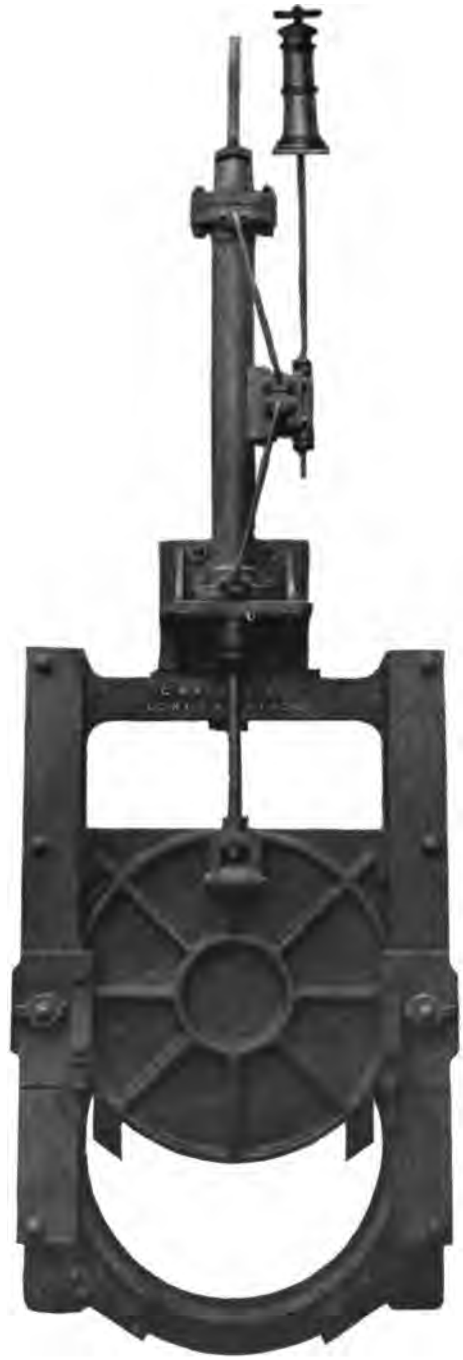


FIG. 17.—HYDRAULIC PENSTOCK (GEO. WALLER & CO.).

A large size penstock for sewage settling tanks is shown in Fig. 18, as made for Nottingham. It was designed for diverting the storm water from the sewer leading to irrigation works or the outfall sewer. This penstock is also used for drawing off the clear sewage in settling tanks without disturbing the solid matter at the bottom of the tanks.

The combined self-acting flushing gate and door, with grating door for storm water outlet (Fig. 19), has been made by Messrs. George Waller & Co., for home and foreign towns. The illustration shows a branch from the main sewer leading to sewage tanks.

At the entrance is fixed a grating door and beyond is a whole flushing door, connected by a rod with a flushing gate in the main sewer. When the sewage rises to a fixed height (below the top of the large flushing gate) it acts upon the tilting apparatus, which opens the large flushing gate and closes the whole flushing door, causing the storm water to pass to the outfall. As the level of the sewage falls the flushing gate closes and opens the flushing door again.

In addition to the foregoing examples there are numerous other useful appliances that may be employed in connexion with the construction of a modern main-drainage scheme.

Where the surface levels of a district to be drained are such that sewers cannot be laid at sufficient gradients to make them self-cleansing, systematic flushing has to be resorted to, or in other cases the sewers are laid down to proper gradients and the sewage is lifted at suitable points from the low-level into high-level sewers, as accomplished by Shone's hydro-pneumatic ejector system, or Adams' patent automatic sewage lift.

Flushing is best done by suddenly and automatically discharging a large volume of water into the sewer from a flushing tank (usually underground in the case of sewers), which is effected by means of a siphon suitably fixed.

There are several good forms of flushing apparatus largely used, viz., Rogers Fields', as made by Messrs. Stone & Co., of Deptford (Fig. 20); Miller's, Adams', Palmer's, and Messrs. Mather and Platt's (Fig. 21).

Another effective method of flushing is that introduced by Messrs. Merryweather in their patent hydraulic sewer flusher, the application of which is shown in the accompanying illustration (Fig. 22).

> It consists of a cylinder, provided with small perforations, arranged to be drawn through the drain from manhole to manhole, having hose attached and connected to a pumping engine or hydrant. The water under pressure radiating from the flusher during its passage thoroughly washes the interior surfaces of the sewer. The engine is of course not required where sufficient pressure is available from the main. This system may be used in 6-in. pipes as well as in large sewers, a copper float in the former case being sent through from manhole to manhole to carry the line by which the rope attached to the flusher is hauled through the sewer.

In the sewerage of towns, districts which lie at a low level with respect to the outfall have frequently to be dealt with, and in this connexion some convenient and economical means of power transmission becomes an important factor. Great improvements have been made during the past few decades towards the effectual drainage of such areas, and the use of compressed air for this purpose has been extensively and successfully adopted. Air transmission has many advantages; its details are simple and the necessary mechanism is well understood. It may be employed at a low pressure, and is well adapted as a motive

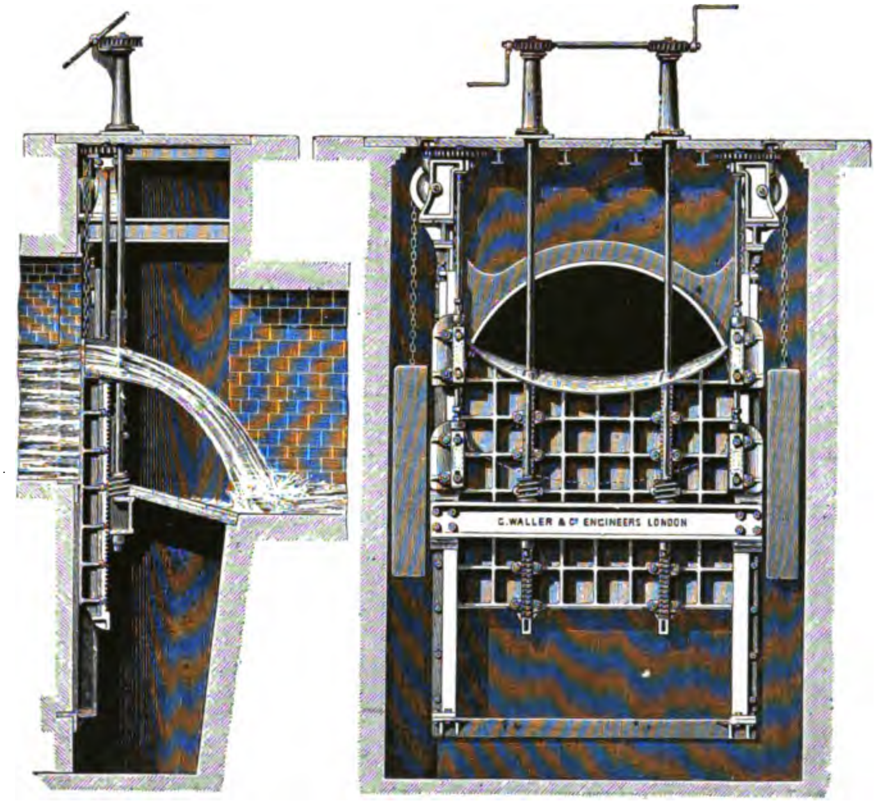


FIG. 18.—WEIR PENSTOCK FOR SEWAGE SETTLING TANKS (GEO. WALLER & CO.).

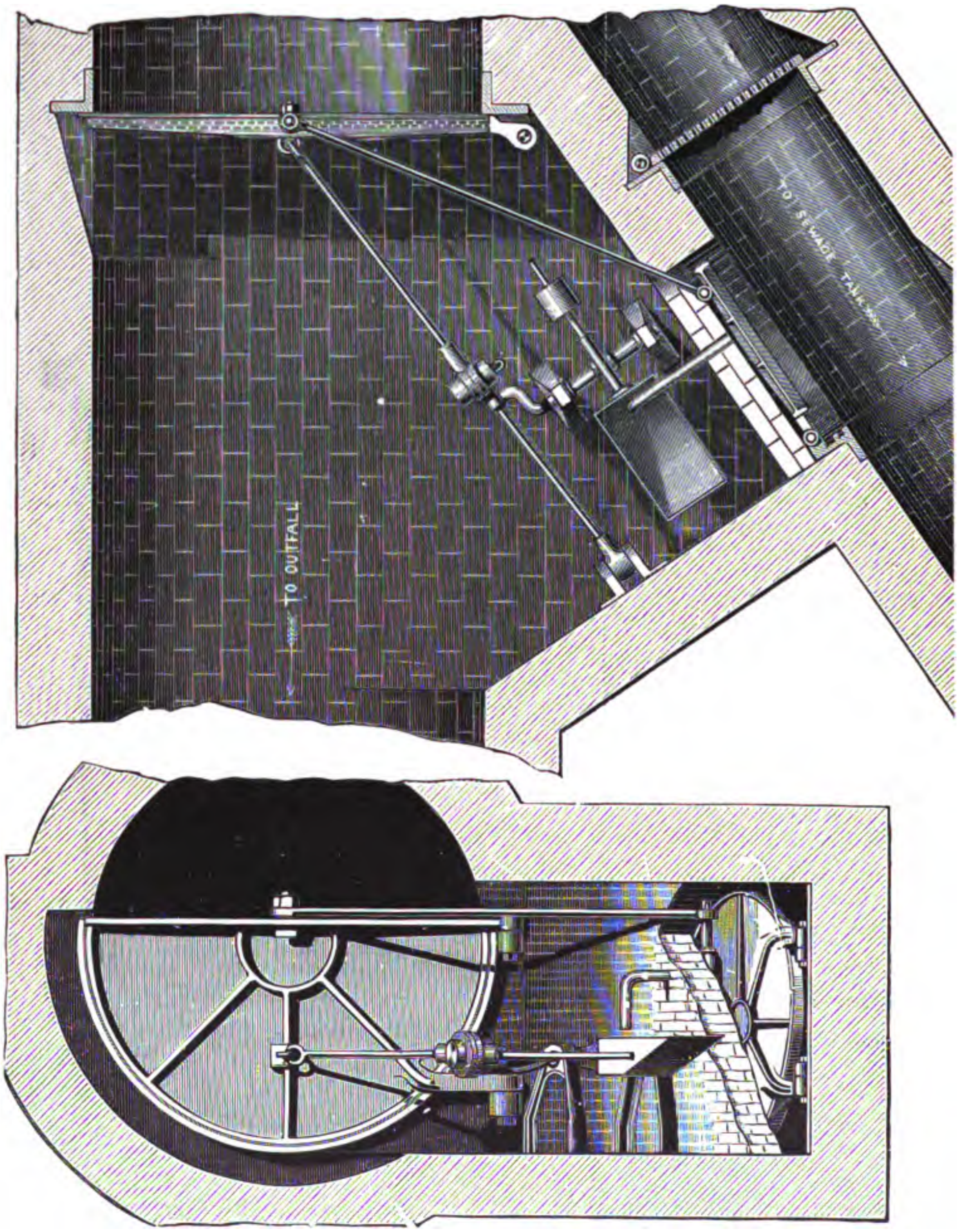


FIG. 19.—COMBINED SELF-ACTING FLUSHING GATE AND DOOR (GEO. WALLER & CO.).

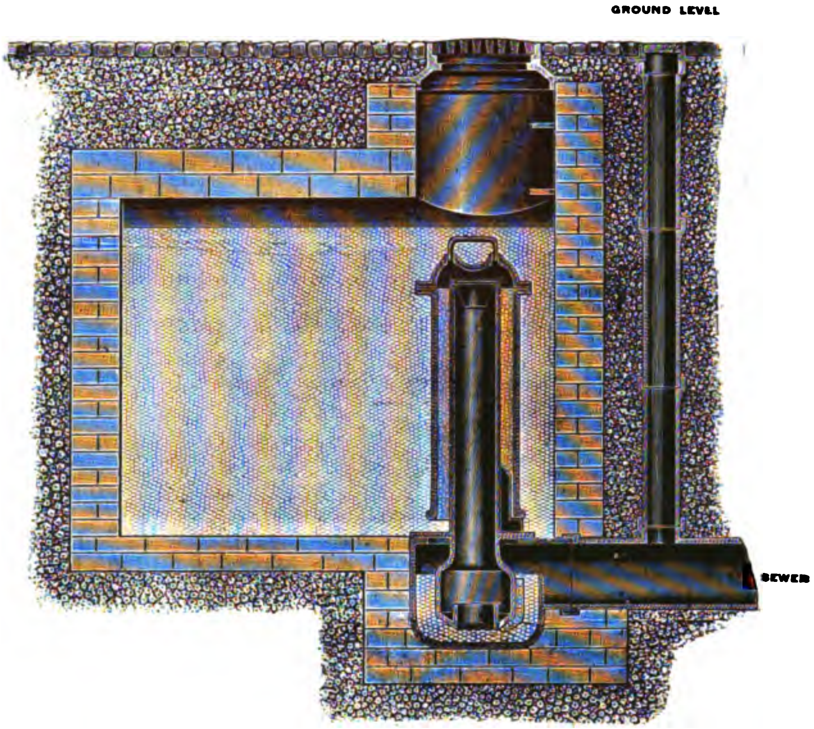


FIG. 20.—AUTOMATIC FLUSHING SIPHON (J. STONE & CO.).

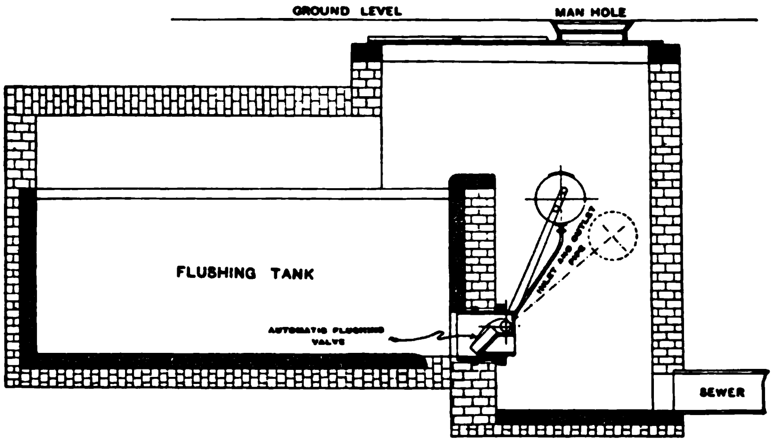


FIG. 21.—AUTOMATIC FLUSHING VALVE (MATHER & PLATT, LTD.).

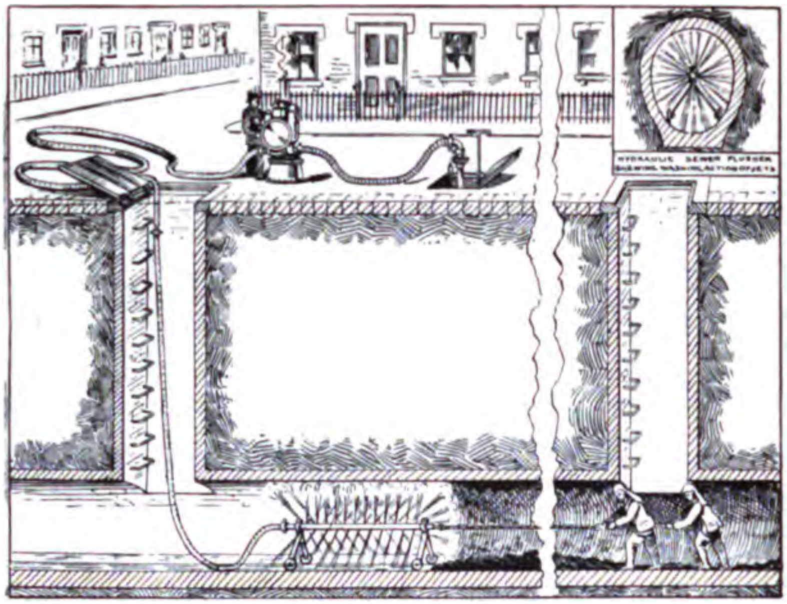

HYDRAULIC SEWER FLUSHER
SHEWING WASHING ACTION OF JETS

FIG. 22.—HYDRAULIC SEWER FLUSHER (MERRYWEATHER & CO.).

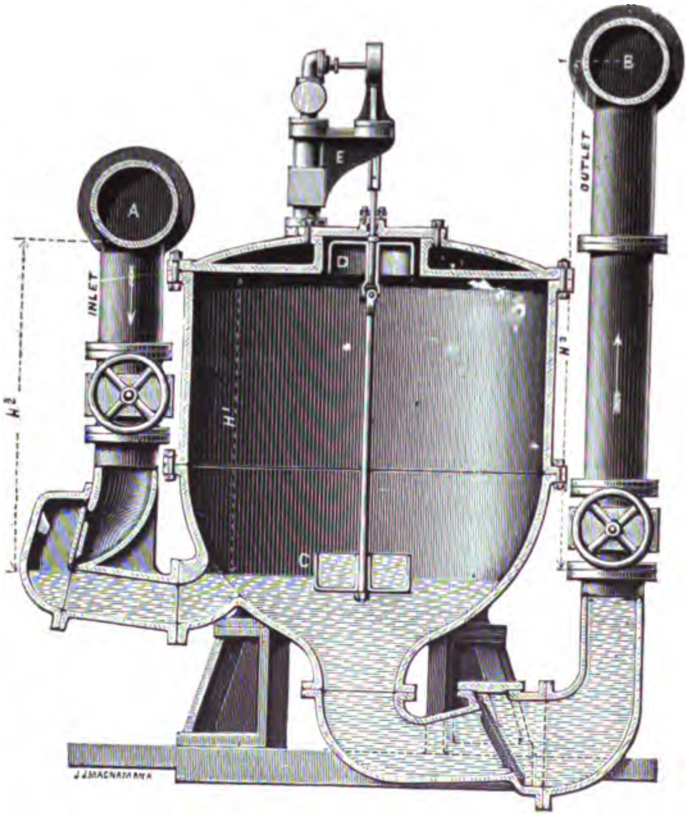


FIG. 23.—CROSS SECTION OF SHONE'S PNEUMATIC EJECTOR (HUGHES & LANCASTER).

power in a simple and reliable pumping arrangement. The many compressed air installations throughout this country and in the Colonies furnish abundant practical proof that with properly jointed and correctly proportioned mains the losses by leakage and friction, even through many miles of pipes, are insignificant. In hydraulic transmission of power a great pressure must be employed, generally over 700 lb. to the square inch, involving greater risks of leakage and a more costly and complicated installation. With air a velocity in the mains twenty times greater than that permissible with water may be permitted without appreciable frictional loss, and more power may therefore be transmitted through a 6-in. main with 45 lb. air pressure to the square inch than with 750 lb. water pressure.

Compressed air has been well applied in "Shone's hydro-pneumatic sewerage system," as installed by Messrs. Hughes & Lancaster of Ruabon and Westminster, which may be employed wherever the sewage of a district requires to be raised. Briefly described, it is a system of distributed stations for the lifting of low-level sewage, worked from one central station by means of compressed air, whereby the whole drainage area is divided into a number of compact districts, each with its separate outfall and discharging station, the discharge from all the stations converging into one common main leading to the ultimate common outfall. For its application the area to be drained is divided into a convenient number of sub-districts or drainage areas, and each provided with an "ejector" station, to which the sewage of that sub-district gravitates, and is there lifted into another sewer situated at a higher level through which it then gravitates again to the outfall. The "ejector" (Fig. 23) is simply an iron vessel placed under the roadway, into which the sewage of the district flows until it is full, when compressed air is automatically admitted, by means of the rising liquid, on to the top of the sewage, thus ejecting it in a few seconds into the main outfall sewer, the process repeating itself automatically as long as there is sewage to flow.

Some 200 installations of this system are now in successful operation in various parts of the world, amongst which may be named a few of the largest, viz., Southampton, Eastbourne, Preston (Lancashire), Hampton, Norwich, Rangoon (Burma), Bombay, Wellington (New Zealand), and Cape Town. The Rangoon installations were put down between the years 1889 and 1894, and the ejectors are capable of dealing with about 24 million gallons per twenty-four hours. The Bombay installations were laid down in 1895, 1900, and 1902 for the sewerage of the Colaba, Mazagaon and the Parel and Ferguson Road districts, and the ejectors deal with about twenty-three million gallons in twenty-four hours. Fig. 24 is an internal view, showing the air-compressing engines made by Messrs. Hughes & Lancaster, at the Love Grove Station of the Bombay sewerage on the Shone system; and Fig. 25 is an external view of the air-compressing station. A large contract for the drainage of Oporto upon this system has also recently been entered into.

In designing the sewerage of a town it often happens that a district having a small volume of low-level sewage to raise has also in its higher levels the power necessary to do this work, and for such a case the automatic sewage lift supplied by the Adams' Patent Sewage Lift Company of York is a very serviceable apparatus. The principle upon which it is based is the compression of air by the falling of a certain volume of sewage or water through a given "head," by means of which a corresponding volume of low-level sewage is raised against a smaller head.

For example, the contents of the low-level sewer L in the accompanying illustration (Fig. 26) are raised to the outlet at K in the following manner: The automatic flush tank A is supplied from the water supply mains and discharges, when full, to the air cylinder D beneath. The air contained therein is displaced by the incoming liquid, being sent through the air pipe F to the forcing cylinder G below. Sewage from the low-level sewer L is admitted to, but cannot return from, the latter cylinder, a plain flap valve being placed at its entry. The height or pressure due to the column from A to D is greater than that on the discharge pipe or rising main H. Air is therefore transferred from D to G under a greater pressure than that which obtains in the rising main H; and, as the flush tank discharges to D, so will the contents of G be discharged to the sewer, until the cylinder D, being full of liquid, an excess in the flush tank passing over a siphon pipe placed within the column, will bring about siphonic action, and the contents of D will be drawn off by this siphon and delivered to the chamber and sewer at K. The supply to the flush tank is controlled by a ball valve, which, rising or falling with the sewage, entirely shuts off the supply when there is no sewage to lift.

The same principle may be employed for raising low-level sewage into an intercepting or outfall sewer by utilizing the fall of sewage from a high-level sewer, as illustrated in the accompanying sectional diagram (Fig. 27). It will be obvious that, provided there is an excess of power over work to be done, the relative positions of the parts of the system are immaterial.

This " lift " is also suitable for cases where it is desired to construct underground conveniences in positions where the sewer is not of sufficient depth, and an installation of this description is given in Fig. 28.

At Stansted, Essex, an improved pneumatic sewerage system has been installed by the Liernur English Syndicate. The area to be drained is divided into districts, each provided with a " district reservoir," from which the sewage is pneumatically extracted and conveyed to a receiving reservoir at the central station by means of a vacuum pump, maintaining a vacuum not exceeding half an atmosphere.

The problem of the efficient *Ventilation* of sewers and house drains is one that has occupied the serious attention of engineers and scientists for many years past, and the public authorities of this country have spent considerable sums upon the efficient ventilation of the main drainage systems under their charge. The various conditions which affect the satisfactory working of a ventilating system have been closely studied by numerous observers, and a decided progress has resulted from their joint labours. The causes of failure and the difficulties of the subject are much better understood than was formerly the case, and the necessity for sound sewerage, good gradients, and quick velocities, as means tending largely to prevent the generation of sewer

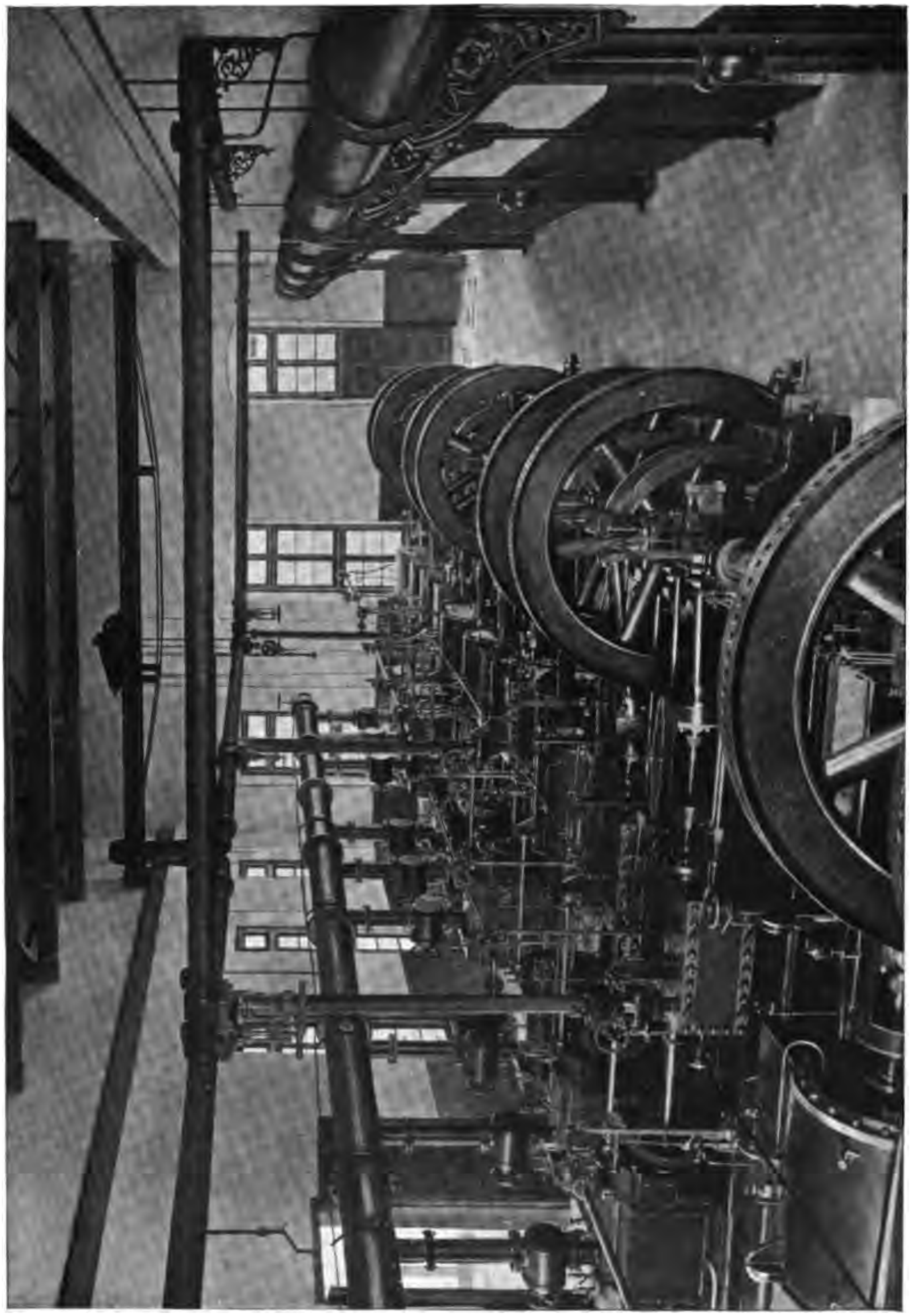


FIG. 24.—VIEW OF AIR COMPRESSING STATION, LOVE GROVE—BOMBAY SEWERAGE (HUGHES & LANCASTER).

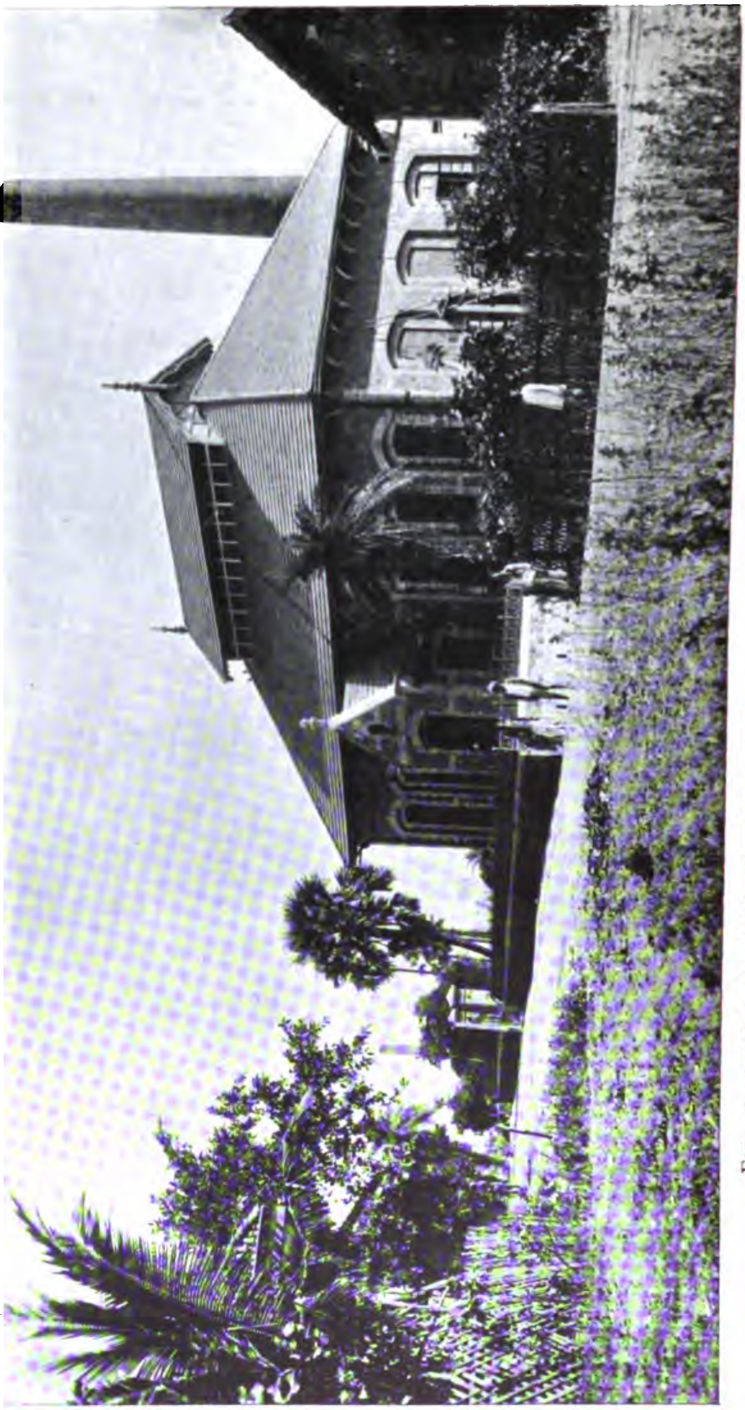


FIG. 25.—BOMBAY SEWERAGE. EXTERNAL VIEW OF AIR COMPRESSING STATION AT LOVE GROVE.

gases, have long been established as principles of sound sanitation. As in so many other departments of practical sanitary work, much new light has also been gained by the application of the teachings of bacteriological science.

Ventilation is effected either by *natural* or by *artificial* means: the former depending principally on the relative temperatures or densities of the air inside and outside of the sewers or compartments to be ventilated, whilst the latter system recognizes the variable and uncertain nature of these natural conditions, and employs some artificial motive power to set up and maintain the necessary current of air within the sewer.

On the natural system the *inlets* for fresh air are arranged at a low level and the *outlets* carried up to a considerable elevation by means of ventilating shafts placed at intervals along the line of sewer. Good examples of such shafts are manufactured by Messrs. Ham, Baker & Co. of Westminster, by the Adams' Patent Sewage Lift Company of York, by Messrs. F. Bird & Co., and others. When heat, such as a gas jet, is applied to such ventilating columns, as is done in "Webb's patent sewer gas extractor and destructor," the ventilation becomes *artificial*, and of late years there has been a decidedly increased tendency to employ mechanical power to all classes of ventilation, with the object of making its action more certain and reliable.

Of such mechanical means I should refer to Shone and Aults' system, whereby the exhaust air from their sewage "ejectors" is utilized and adapted for the drawing in of fresh air through suitable inlets provided and the discharge of foul air through tall ventilating columns. The same firm has also recently patented a mechanical means of ventilating public sewers and house drains, which is based upon regulating the admission of fresh air to the drains and sewers, through suitably arranged inlet valves, in such a manner that each connexion to the sewer shall contribute its proper quota of volume of air and no more, but that such quota shall be ample in volume to efficiently ventilate (*a*) the house drain into which it is admitted, and (*b*) the sewer with which the house drain is connected. In this system the current in the sewer is maintained by means of a fan, such as a " Blackman," or a " Sirocco."

The Reeves' system of ventilation is intended to produce oxidation of the sewer air by artificial means when natural oxidation fails. The gases as generated are destroyed in specially prepared manholes by the aid of an admixture of chemicals supplied to the sewage by an apparatus which is fixed within the manhole.

Sewage Disposal

OF all branches of municipal work there is none which has so generally engaged the serious attention of the public authorities of Great Britain, great and small alike, as that of "sewage disposal," and there is perhaps no department of scientific inquiry which has been more troublesome in the past, and in respect of which the methods of present-day practice have been so completely revolutionized during the past few years. The duty of satisfactorily disposing of about 240 million gallons of sewage *daily*, as in the case of London, or of about 37 million gallons a day, as in the case of Manchester, is no small task, bearing in mind that these large volumes of that highly complex and variable liquid which we call "sewage" must be dealt with in a manner that shall satisfy all the present-day ideas in advanced sanitation, so far as they have been well established, and at the same time the treatment adopted must be thoroughly practical, and not too heavy a financial burden upon the community.

In earlier times, before the centralization of large masses of population into cities and towns, there was no difficulty. Nature's methods, which we are at last beginning to understand, quietly effected all that was necessary to rid the earth of the various foul and waste materials produced by animal and plant life. This important work, as is now known, is performed by myriads of invisible unpaid scavengers, which we call "bacteria," and whose very existence was not even suspected until quite within modern times.

Though paradoxical, it may be said with reference to the sewage problem that we have been *slow* yet *fast* in arriving at a satisfactory solution. Slow in placing ourselves upon the right lines of inquiry, but fast in developing and applying our knowledge as soon as the true significance of the biological principles involved had been fully appreciated. In addition to a huge army of private investigators into this problem, there have been from time to time numerous Royal Commissions on sewage disposal, river pollution, water supply and allied branches, and a large mass of useful information has been thus accumulated. Innumerable schemes have been brought forward in the past, and many different methods of treatment are in use to-day. These, however, may, I think, be all classified under one or other of the following heads or systems, viz. the dry-earth system, discharge into the sea or tidal estuary, irrigation, filtration, precipitation, evaporation (as by Liernur's English Syndicate), electrolysis (Webster's process), and bacteriolysis.

Experience has shown that none of these methods, save the last, when put to the test of practical proof, have proved satisfactory. Irrigation and the dry-earth systems are in reality bacteriological methods, but for large populations are quite impracticable. For example, the acreage recommended by the Rivers Pollution Commissioners was on the basis of one acre of suitable land per 150 of the population, so that London would now require an area of over 60 square miles of land laid out as an irrigation sewage farm! At the same time, however, the fact must not be disregarded that for small provincial communities, where a sufficient quantity of suitable land can be reasonably obtained, broad irrigation becomes an excellent solution of the sewage problem. The whole process of treatment thereon is a bacterial one—the land under suitable conditions serving a precisely similar purpose to prepared bacterial "contact-beds," but with this important difference, that prepared beds are very much more under control, and, area for area, are vastly more efficient. The many chemical methods in vogue may also be safely dismissed as cumbersome, excessively costly in chemicals, labour, and disposal of sludge; and as soon as the effluents become sufficiently diluted with pure water putrefaction sets in.

Present-day research, therefore, is almost wholly directed to the perfecting and introduction of bacterial methods of purification, in which so much is voluntarily done by nature when the requisite conditions are not violated by man. In the development of this system the bacteriologist, the chemist, and the engineer must work side by side in their several departments, and in this way a vast amount of original work has been successfully accomplished during the past decade. Amongst the names of those who have done special service in this sphere are those of Cameron, Dibdin, Thudichum, Houston, Clowes, Fowler, Ducat, Rideal, Scott-Moncrieff, and others.

If evidence were needed of the universal difficulties under which sanitary authorities were labouring in connexion with the question of sewage disposal and of the general desire for some improved mode of treatment, it certainly is to be found in the extraordinary interest aroused, it may be said in all quarters of the globe, by the results obtained from the first " bacteria bed " constructed in the United Kingdom for the treatment of crude sewage. Such a bed was laid down by the Sutton (Surrey) Urban District Council, upon the original suggestion of Mr. W. J. Dibdin, in November, 1896, and has proved to be the commencement of a system which has revolutionized all existing methods of sewage purification. The results obtained by this new " Sutton " or " Dibdin " system, as it was called, became known to local authorities in a remarkably short space of time, and representatives and deputations from all parts flocked weekly to view these comparatively small and simple works of the Sutton Council; so great had their repute become, that they have been designated the "Mecca of Sanitary Engineers," and during the year 1898 no fewer than 305 deputations inspected the system. The visitors have included representatives from South Africa, Australia, New Zealand, United States of America, India, Egypt, Germany, France, Austria, Belgium, and other places, and the Council freely accorded to kindred authorities the privilege of benefiting from their own experiments and investigations.

The great features of the bacteria system are its simplicity of design and method of working, the avoidance or reduction of sludge difficulties, smallness of both initial and working costs, and the high degree of purification effected. No system of sewage treatment ever met with such rapid favour or has been so extensively adopted in such a short space of time.

In these days of rapid dissemination of information by the press, technical societies, and other agencies, no discovery or invention can long remain the property of one man, and, whatever may befall the individual, the community gains to a degree beyond all calculation by the manner in which knowledge is now sedulously made public. By the simple process of reading we may day by day keep ourselves informed of the latest progress effected in any department of life in which we may be interested, and in this way during the lapse of a few short years numerous other workers have been led to take up original experimental work in the bacterial treatment of sewage in the endeavour to test for themselves and develop the system initiated at Sutton. Amongst these original workers have been the authorities of London, Manchester, Leicester, Leeds, Bir-

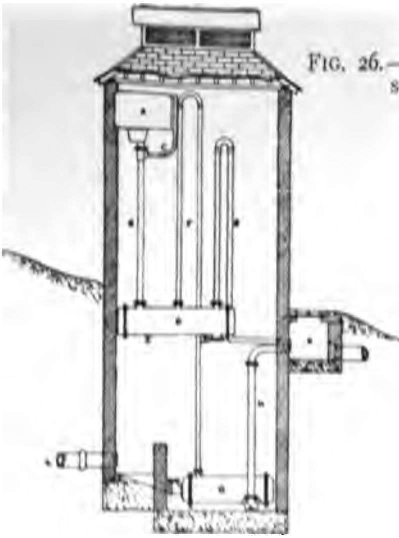
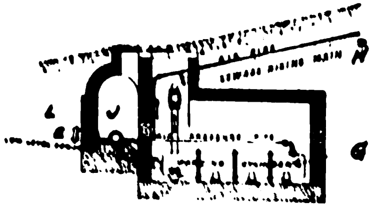
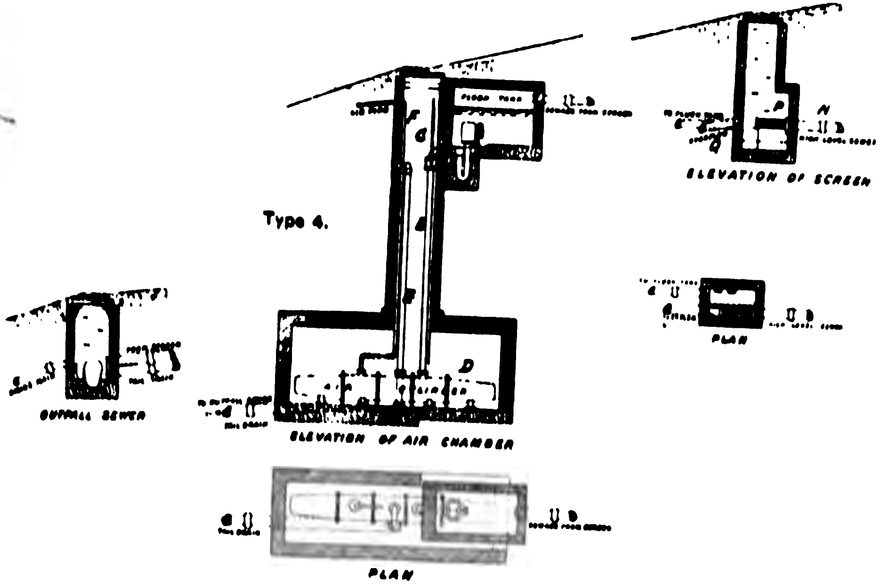


FIG. 26.—ADAMS' AUTOMATIC SEWAGE LIFT.



Low-level Sewage raised to Outfall Sewer.



High-level Sewage utilised to raise Low-level Sewage.

FIG. 27.—SECTIONAL DIAGRAM OF ADAMS' SEWAGE LIFT.

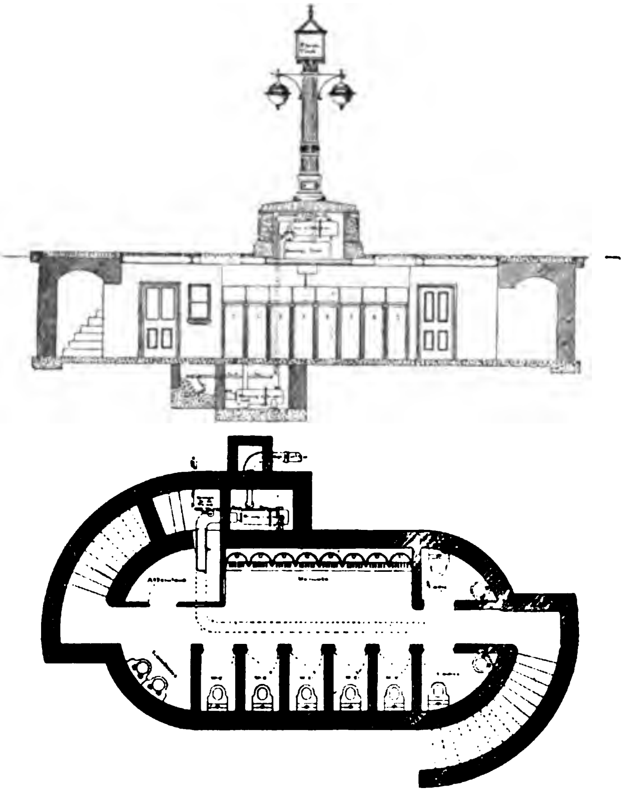


FIG. 28.—ADAMS' "LIFT" FOR UNDERGROUND CONVENIENCES.

mingham, Exeter, and Huddersfield, and the information thus amassed, and published in many excellent official reports, is of the greatest service to the community at large.

About the same time that Mr. Dibdin constructed his bacterial filter at Sutton, Mr. Donald Cameron, the city surveyor of Exeter, was making observations of the action of sewage retained in a covered or " septic " tank, and, in what is now known as the "Septic Tank System," the anaërobic processes taking place in this receptacle are regarded as an essential preliminary to the aërobic action on the sewage, as it is subsequently passed on the " Dibdin " or " Contact " method through bacterial filters.

The object of the septic tank system, as patented by Messrs. Cameron, Commin, and Martin, of Exeter, is to purify sewage by natural means, and so avoid the expenses entailed by artificial treatment. The process aims at the hastening of natural decomposition by bacterial agency, the liquefaction of animal and vegetable solids, and the consequent avoidance of what has hitherto been a very real and costly difficulty—the accumulation of large quantities of sludge, as obtained in the ordinary precipitation and chemical methods of treatment. The septic tank itself is merely a receptacle designed to favour the multiplication of micro-organisms, and bring the whole of the sewage under their influence. To this end the tank is of ample size—though not larger than would be necessary with chemical precipitation—and covered, so as to exclude light and air. The inlet for incoming sewage is placed below the water level, and the outlet is also below water line ; the object being to trap out air and avoid disturbance of the upper part of the contents of the tank. Upon entering the still water of the tank the suspended solids in the sewage are to a great extent disengaged, and fall either to the bottom or rise to the surface, according to their specific gravity. The organisms originally present in the sewage increase enormously in the absence of light and air, and rapidly attack all organic matter. The more complex organic substances are converted by their action into simpler compounds, which in turn are reduced to still simpler forms, the ultimate products of the decomposition in the tank being water, ammonia, carbonic acid and other gases. The effluent water from the tank is passed through bacterial filters, which are fitted with a simple automatic alternating arrangement, by which each filter in turn is filled, discharged, and aërated without attention.

The illustrations (Figs. 29 and 30) show a small but complete installation of the septic tank system, put down for the Manchester City Corporation in connexion with investigations into this mode of sewage treatment made on their behalf by the experts appointed by the Council in May, 1898, and who reported in October of the following year.

The septic tank, it will be observed, is 40 ft. long by 12 ft. wide by 9 ft. 2 in. high, and has an arched roof provided with manhole covers for inspection. The tank is constructed with cement concrete and rendered with cement mortar on exposed faces. It will be noted that before the sewage enters the septic tank it flows through a grit chamber, so as to arrest the coarser detritus. The inlet and outlet to the tank are both below the sewage level, as already mentioned, and light and air are excluded as much as possible. Following the course of the effluent from the tank, it will be seen that it passes into an

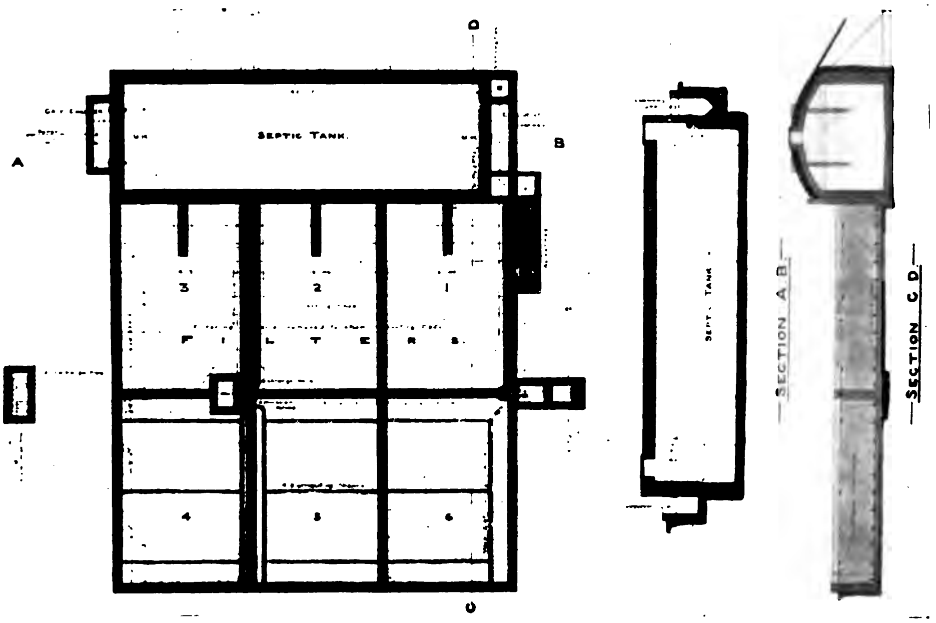


FIG. 29.—PLAN AND SECTION OF EXPERIMENTAL SEPTIC TANK INSTALLATION, MANCHESTER.

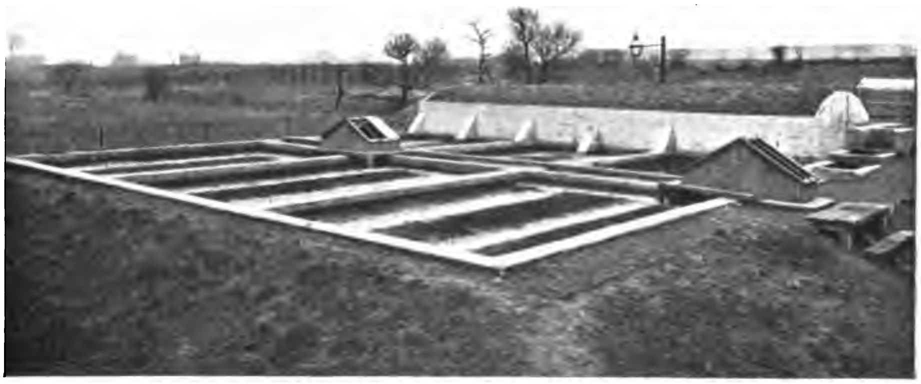


FIG. 30.—PHOTO VIEW OF ABOVE.

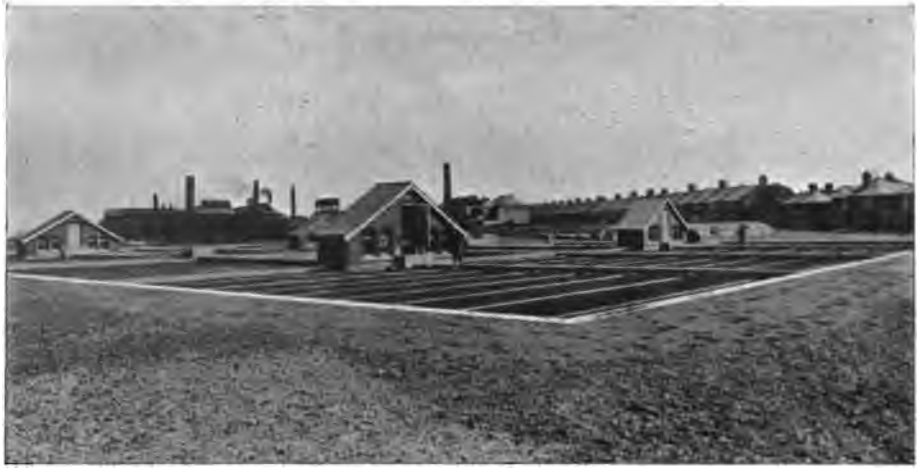


FIG. 31.—BACTERIAL SEWAGE SCHEME AT ITCHEN (SEPTIC TANK CO.), SHOWING WORKS IN CLOSE PROXIMITY TO RESIDENTIAL PROPERTY.

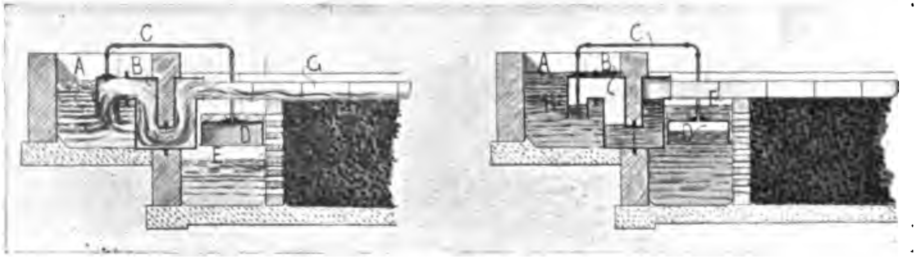


FIG. 32.—ADAMS' "AIR-LOCK" FEED APPARATUS.

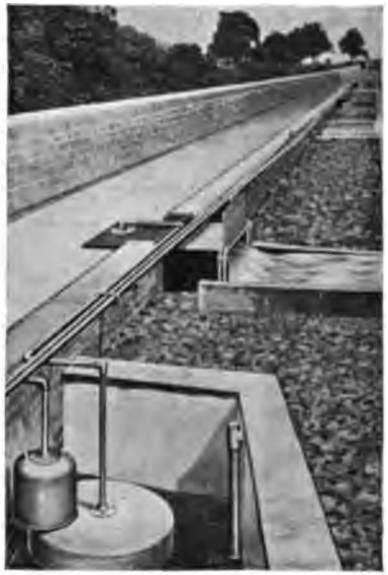


FIG. 33.—AIR-CONTROLLED FEED FILLING A CONTACT BED AT CARLISLE CITY.

> effluent chamber, through a gauge chamber, into a shallow aërating trough, over the sides of which it falls in thin sheets into a channel leading to distributing wells, and so on to the bacterial filter beds. In these wells automatic actuating gear is placed, which admits the effluent to the surface of each bed in succession and draws it off from beneath. The net superficial area of the six beds is 196 square yards. They are enclosed by vertical concrete walls, and arranged as shown in plan, with the chambers containing the automatic gear built into the centre wall. The sewage-distributing troughs are formed of half-pipes laid in the filtering material, the upper edge of each trough being level with the surface of the bed. The filtrate is drawn off by means of 2-in. collecting butt-jointed and perforated drains and 4-in. collecting mains laid on the bottom of the beds as shown. The filtering material is 4 ft. in depth, and commences with 1 foot of clinker to pass a 3-in. mesh and rejected by 1-in. laid on the bottom of the filter, and is then followed by 2 ft. 9 in. of screened clinkers to pass a ¾-in. mesh and rejected by a ⅛-in. mesh, overlaid by 3 in. of residue from the above which will pass a ⅛-in. mesh. The beds are filled and discharged automatically, as explained above. The bed which is discharging shuts the outlet and opens the inlet valve of the bed to be filled next, thus securing " intermittent contact " on the Dibdin principle.

The bacterial purification of the sewage is brought about somewhat in the following manner. The bacteria which already exist in the sewage are brought by it into the septic tank and on to the filters. The bacteria beds provide an enormously extended surface for the development of bacterial growths, and thus furnish an ideal habitat for the aërobic micro-organisms requiring air (oxygen) for the performance of their natural functions, whilst the septic tank, with its very limited supply of light and air, enables the anaërobic micro-organisms to work to the greatest advantage. The amount of sewage which can be purified in the septic tank or bacteria bed gradually increases with age, as some time must elapse before the bacterial life attains its maximum.

After having carefully considered the experimental and other evidence before them, the experts arrived at certain important conclusions on this system of sewage disposal, substantially as follows—They found (*a*) that the bacterial system was the best adapted for the purification of the sewage of Manchester, and that any doubts which may have arisen in the first instance as to the suitability of this mode of treatment, owing to the presence in the Manchester sewage of much manufacturing refuse, have, through the convincing results of the experimental work, been entirely banished. (*b*) That for obtaining a high degree of efficiency a system of multiple " contact " is generally necessary. It may be taken broadly that in the first contact 50 per cent. of the dissolved impurity is removed, and that in the second contact 50 per cent. of the impurity still remaining in the effluent is disposed of, and so on. (*c*) That the sewage should be first placed through a septic tank, in order that the contact beds may be protected from the mineral and suspended organic matter in the sewage, and that as much of the organic matter as possible may be destroyed by the anaërobic bacterial process, thereby rendering the sewage more uniform and reducing it to a favourable condition for nitrification to take place. (*d*) That the open septic tank is as efficacious as the closed, and that in order that a bacterial contact bed may exercise its full powers of purification, it is necessary that it should be allowed sufficiently frequent and prolonged periods of rest, that the sewage applied to it should, as far as possible, be free from suspended matter and be as uniform in character as possible. (*e*) That the capacity of bacterial contact beds has been found to remain practically constant after they have been in operation for a period of three months; and that in the event of a bed having been unduly taxed, its efficacy is only temporarily impaired and can be restored by a few days' repose. (*f*) The experiments showed that the bacterial system is efficacious at all seasons of the year, the temperature of the sewage being sufficient both to prevent any stoppage of the beds by the formation of ice, and also to maintain the necessary activity of the bacteria even in the coldest weather. (*g*) With regard to the treatment of the increased flow during rain, i.e. of "storm water," the experts were of opinion that provision must be made for the storage of the "first flush" of sewage at the beginning of a storm, and that it is probable that accelerated treatment may be commenced about two hours after the augmented flow has begun to reach the works; also, that adequate purification of storm water can be effected by short double contact, or, in the case of extreme dilution even by single contact, the length of the cycle being inversely proportional to the flow of sewage. It was also proved by the experiments that when, after a storm, ordinary treatment is resumed, the beds show no decrease in purifying efficiency.

The percentage of purification at the Manchester experiments ranged from 73·5 to 77·7 per cent. in albuminoid ammonia, and from 79·1 to 82·2 per cent. in oxygen absorbed in four hours. These results were attained by a single filtration following septic treatment. At Leeds, where similar experiments have also been carefully made, chiefly with double contact beds—a rough and a fine bed working in pairs—the percentage of purification ranged from 85·1 to 86·9 per cent. in albuminoid ammonia and from 89·3 to 92·8 per cent. in oxygen absorbed. The official report on the Leeds experiments gives the following general observation on the filtrate from the contact beds—"From experience gained during over two years in treating Leeds sewage on contact beds, it was found that whether dealing with crude sewage, screened sewage, or partially settled sewage, variable but very good effluents could be obtained, much superior to those from lime precipitation. Their chemical analyses gave results which were generally well within the limit of one grain per gallon oxygen absorbed and ·1 of albuminoid ammonia—limits which have in recent years been accepted by the Lancashire and Yorkshire River Boards as a provisional standard of purity for effluents going into a stream not used for drinking purposes."

In the septic tank gases generated by the decomposition of the sewage therein quickly accumulate. At Exeter, the following composition was ascertained by analysis—carbonic acid, 36·8 per cent.; marsh gas, 42·4 per cent.; and hydrogen, 20·8 per cent., by volume. The calorific value of the gas is found to be from one-half to two-thirds that of London coal gas. Though not luminous in itself, a good light is emitted when burnt under an incandescent mantle, and several septic sewage works are lighted in this way. Experiments have also been made in the utilization of the gas for power production by burning it under a boiler and raising steam, and also by explosion in a gas engine.

The experimental treatment of London crude sewage in coke-beds has been carried on for some years at the Barking and Crossness outfall works of the London County Council. Raw sewage is roughly screened and pumped into a settling tank of six hours' capacity, and in which it is found that a considerable proportion of the sludge disappears by bacterial action. During the first six months, 23·7 per cent. of the sludge so disappeared, and during a subsequent similar period 50 per cent. The settled sewage is then flowed on to a coke-bed or filter of six feet in depth, and which is worked on the two-hours' "contact" method. The bacterial effluent is then drained off, and the bed stands empty for two hours. Four charges of settled sewage are received and purified in twenty-four hours.

The experiments have been conducted throughout under the supervision of the Council's chemist, Professor Frank Clowes, D.Sc., F.I.C., and the conclusions he has arrived at are—

1. "That by suitable continuous undisturbed sedimentation the sewage is deprived of matter which would choke the coke-beds, and the sludge which settles out is reduced in amount by bacterial action to a very considerable extent. This reduction might undoubtedly be increased by the preliminary removal of road detritus.

2. "That the coke-beds, after they have developed their full purifying power by use, have an average sewage capacity of about 30 per cent. of the whole space which has been filled with coke.

3. "That the sewage capacity of the coke-bed, when the bed is fed with settled sewage, fluctuates slightly, but undergoes no permanent reduction. The bed does not choke, and its purifying power undergoes steady improvement for some time.

4. "That coke of suitable quality does not disintegrate during use.

5. "That the 'bacterial effluent' of settled sewage from the coke-beds does not undergo offensive putrefaction at all, even in summer heat, and can never become offensive. That this effluent satisfactorily supports the respiration of fish.

6. "That the use of chemicals is quite unnecessary under any circumstances when the above method of treatment is adopted."

The recommendation made by Dr. Clowes to the London County Council, founded on the above conclusions, was, in his fourth report (April, 1902), to the effect that "it would appear desirable, without delay, to commence the treatment of the London sewage by the above bacterial method."

At Huddersfield, where some 30 per cent. of the sewage is derived from manufacturing processes, the best results were obtained by treating first with a small quantity of lime and sulphate of iron, followed by double contact in bacteria beds. The beds used for this purpose retained their capacity much better than those which dealt with either the crude sewage or with the septic tank effluent.

Bacteria beds are worked either on the "Dibdin" or "contact" system, in which the periods of rest and work are regulated by means of alternating gear, or upon the "continuous" or "trickling" system, in which the sewage is uniformly spread over the filters by means of rotary "distributors."

Messrs. Adams Hydraulics, Ltd., of York, are manufacturers of all classes of apparatus and fittings for bacterial sewage disposal, and have fitted up a very large number of installations with their well-known air-lock feed apparatus, siphon discharge for effluent, from the beds, revolving distributors, and other fittings. The whole of this apparatus is entirely automatic in its action, being worked

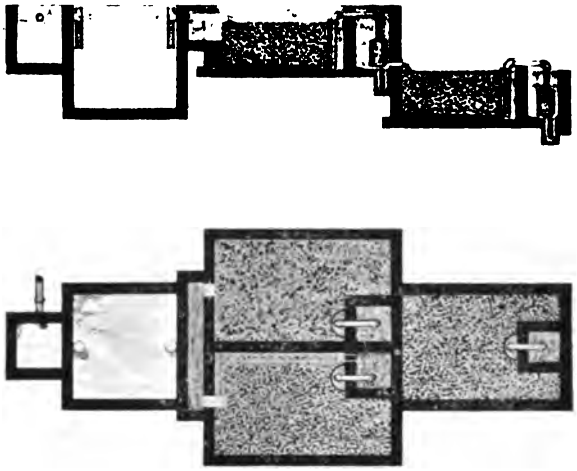


FIG. 34.—PLAN AND SECTION OF TWO PRIMARY AND ONE SECONDARY BED, WITH ADAMS' FEED AND DISCHARGE SIPHONS.

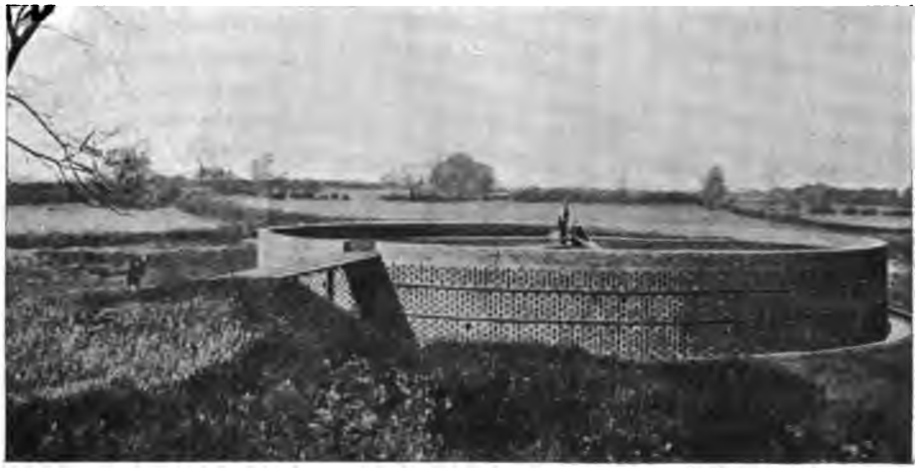


FIG. 35.—THE "YORK" CONTINUOUS FILTER (ADAMS AND CO.).

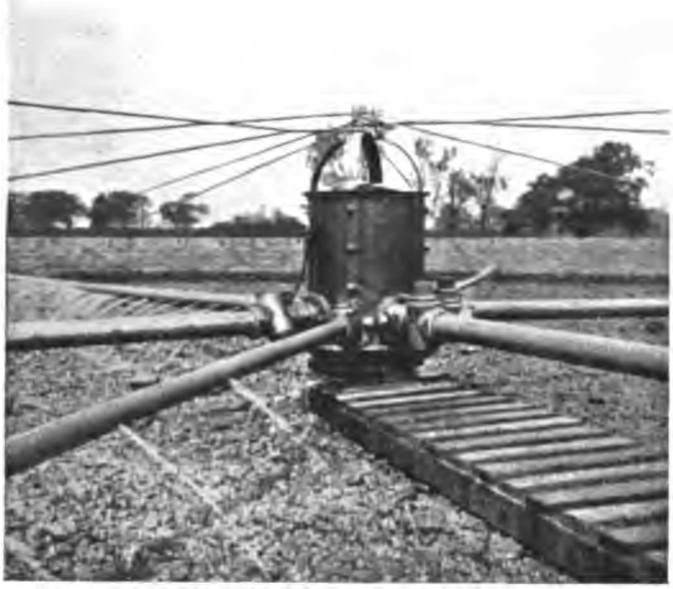


FIG. 36.—THE "YORK" DISTRIBUTOR (ADAMS AND CO.).

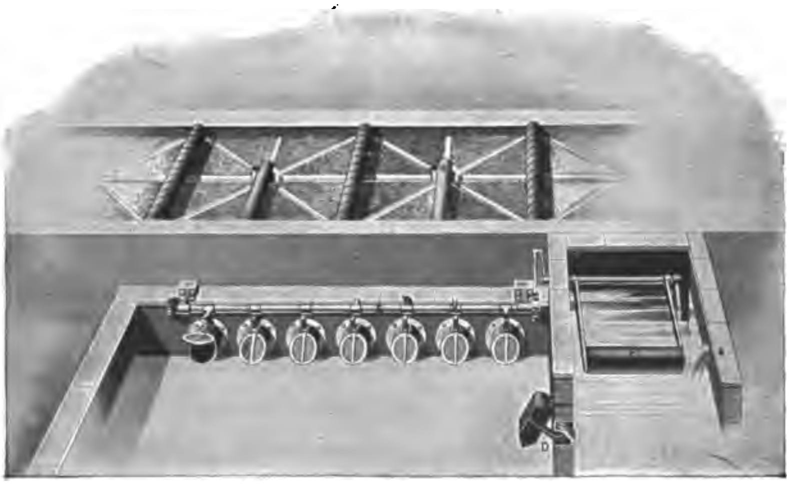


FIG. 37.—AUTOMATIC FEED TO BACTERIA BEDS (MATHER AND PLATT, LTD.).

by the flow of the sewage itself. By its means the beds thus fill, stop off their own supply, stand full for the desired period of contact, empty, stand empty, and re-fill in regular or any desired sequence.

The whole of the feeding and discharge operations to the different beds are thus done with a clock-like regularity and economy not possible with manual labour. The leading principle employed is the " air-lock " feed shown in Figs. 32 and 33, in which the rising of the sewage in the channel E imprisons air in the dome D, which is transferred by pipe C to the interior of the syphon feed B, thus causing an " air-lock " and shutting off the supply of sewage to the bed. The unlocking or re-opening of the feed is brought about by the escape of this air, caused by the introduction of an added volume from a smaller dome in any adjoining bed bursting the seal of the trap or syphon feed. Fig. 33 is a view of the air-controlled feed filling a contact bed (Carlisle city), in which is seen the feed in action, the large dome and air pipes causing the air-lock, and also the small dome above referred to for re-opening the syphon-feed by bursting its seal. Fig. 34 is a plan and section of two primary and one secondary bed fitted with Adams' feed and discharge syphons, as above described, with catch pit and scum tank for the removal of suspended matter before the sewage is passed on to the bacterial beds.

The " York " continuous filter is illustrated in Fig. 35, as installed at the York city sewage disposal works by Mr. A. Creer, C.E., the city engineer, and in which the walls of the filter are of openwork for aëration of the bed. The distributor (Messrs. Adams) is shown in action in Fig. 36.

Another system of automatic feed to bacterial beds is that introduced by Messrs. Mather & Platt, Ltd., of Manchester, and illustrated in Fig. 37. Here it will be seen that by the rise and fall of a float placed in a compartment adjoining the distributing chamber, a shaft carrying inlet valves is actuated. This shaft is fitted with cams, which press upon levers opening the inlet valves to the various beds; and these cams are so arranged that each partial revolution of the shaft releases the valve last opened and opens the next in sequence. By the adoption of this device, and Mather & Platt's automatic retaining and discharging valve, a perfectly automatic series of feeding operations is secured at a fraction of the cost of manual attendance and with much greater regularity.

The automatic revolving spreader supplied by Messrs. Mather & Platt for the distribution of the sewage over the bacteria beds at the Bolsover sewage works (Derbyshire) is shown in operation in Fig. 38.

At Saltley, in connexion with the Birmingham Tame and Rea district drainage, two large percolating bacteria beds have been in use some time. They are circular in plan, 120 feet in diameter and from 4 ft. 6 in. to 5 ft. deep. The filtering medium is coke resting on a false floor covering parallel lines of brick channels. To one bed the sewage is applied by the Adams' or York distributor, which is actuated by water pressure on what is known in hydrostatics as the Barker's-Mill principle. The other bed is fed by a Scott-Moncrieff distributor (Fig. 39) consisting of two 60 ft. girders carrying an open trough supplied with sewage from a central pipe, around which the trough rotates. The outer end of this distributor travels on a circular mono-railway, which is supported by girders and brick piers. The rotation of the spreader is effected by a two-horse power oil engine, which traverses the circle in seven minutes. The sewage flows very equally from the distributor on to the bed, and the quantity can be adjusted to suit requirements.

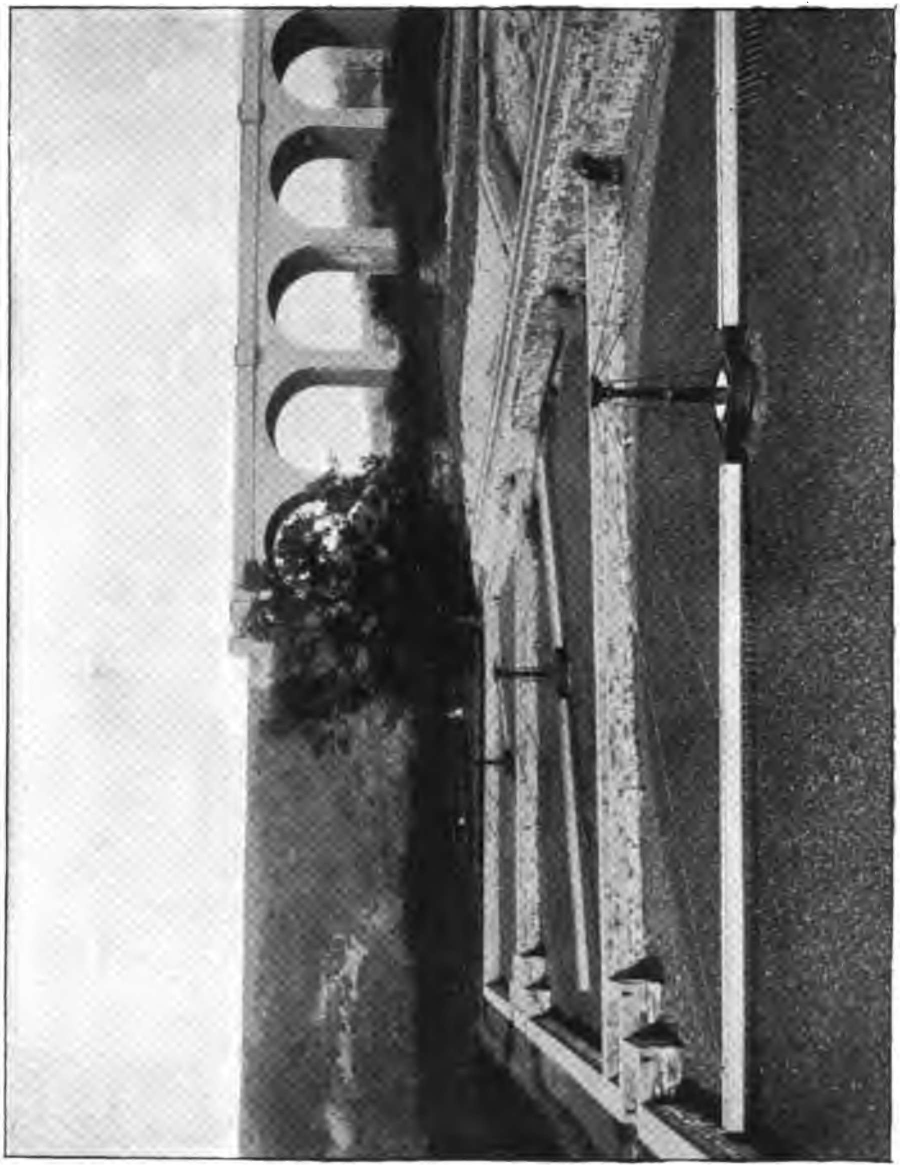


FIG. 38.—REVOLVING SPREADER AT BOLSOVER SEWAGE WORKS (MATHER AND PLATT, LTD.).

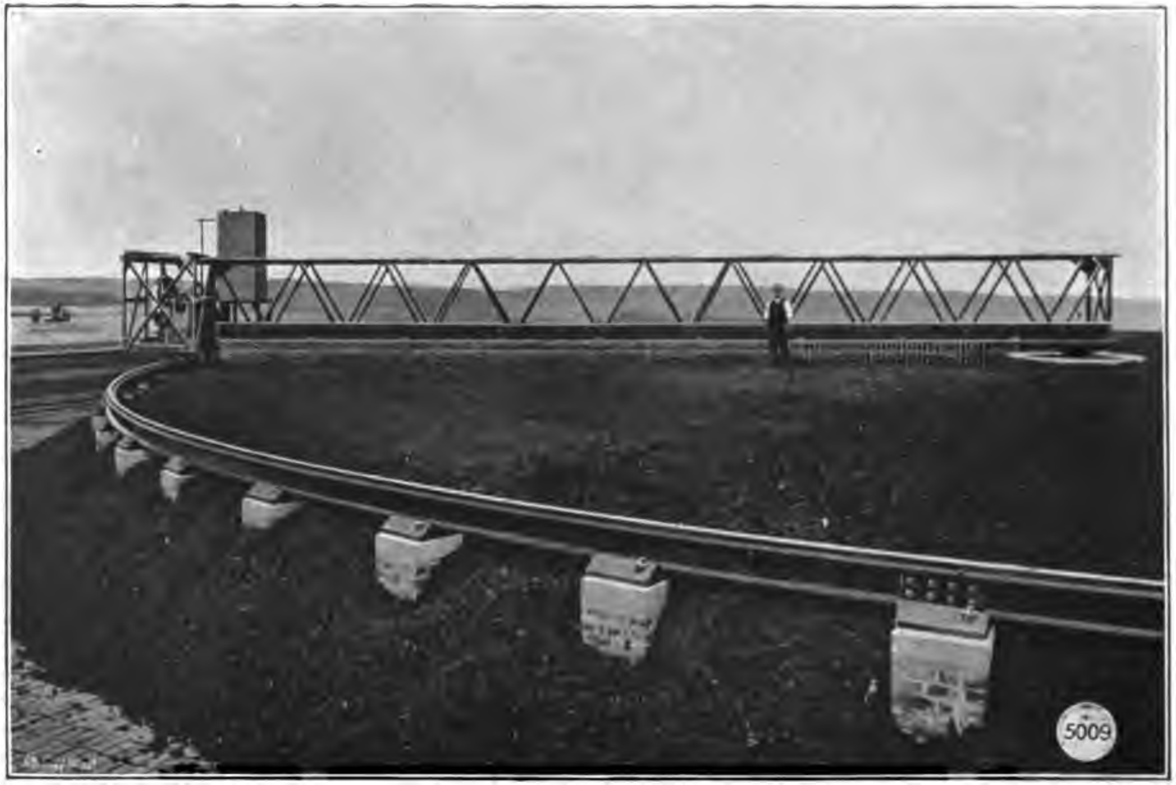


FIG. 39.—THE "SCOTT-MONCRIEFF" DISTRIBUTOR (MANLOVE, ALLIOTT AND CO., LTD.).

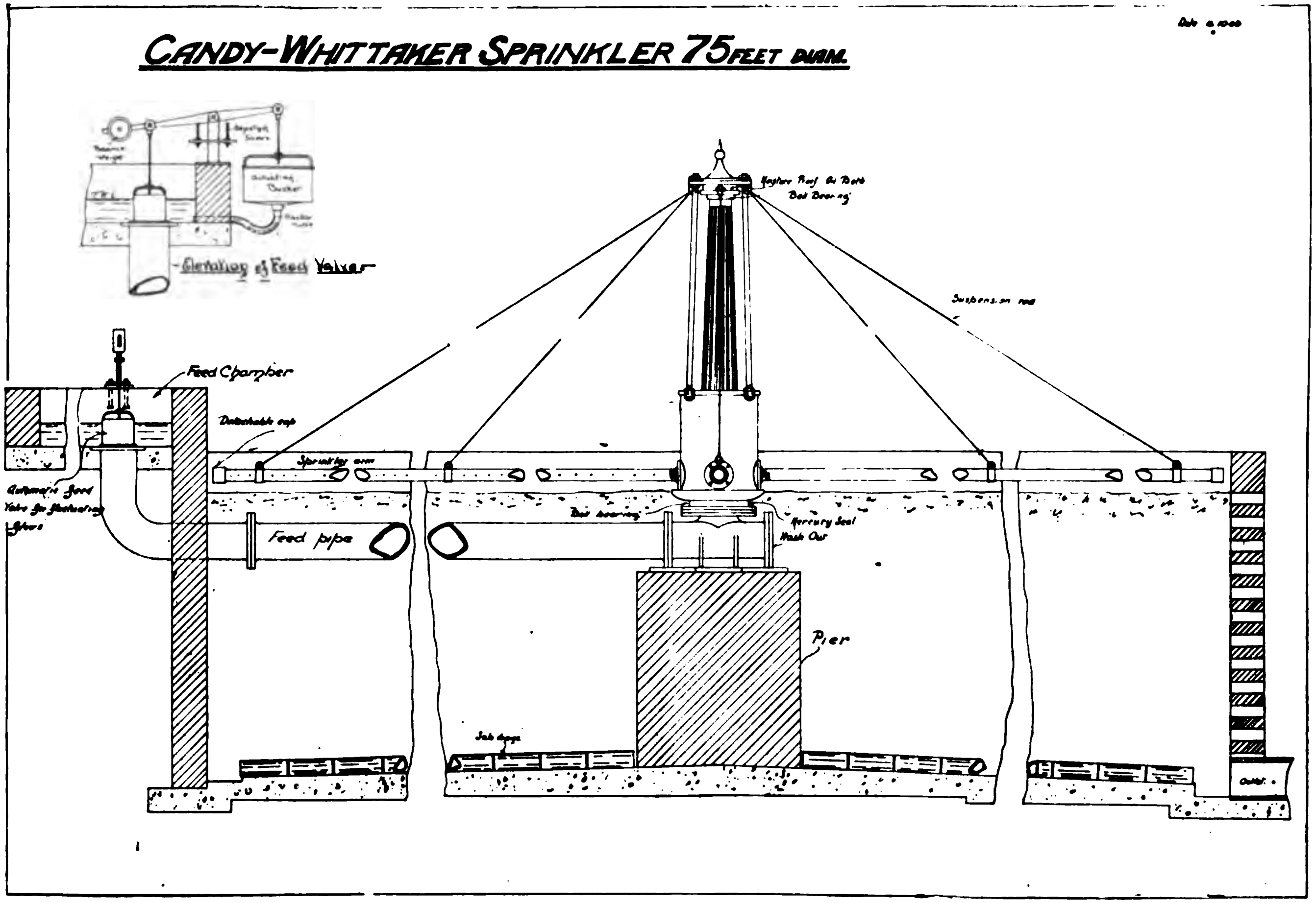
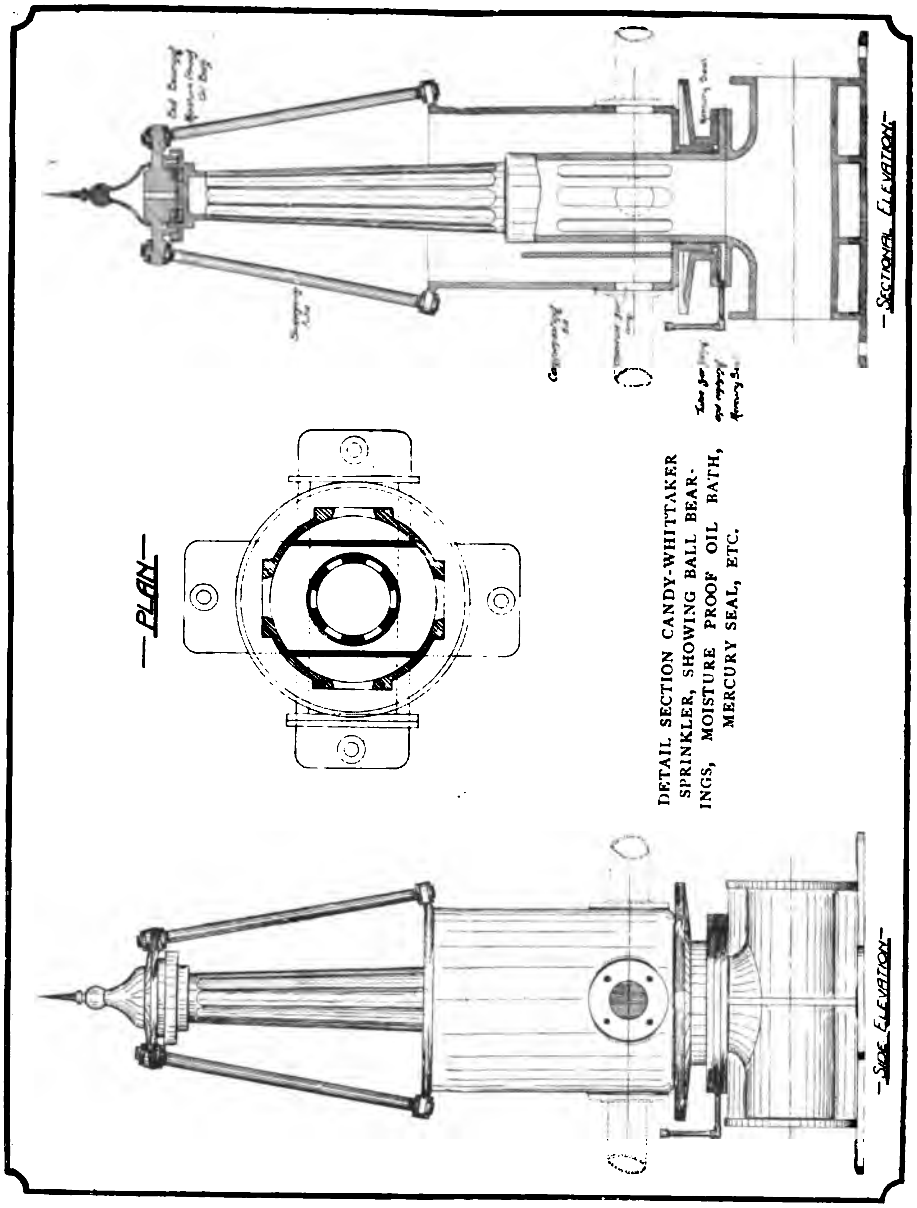

CANDY-WHITTAKER SPRINKLER 75 FEET DIAM.
Balance Weight
Adjusting Screws
Actuating Bucket
Flexible Tube
T.W.L.
Elevation of Feed Valve
Weather Proof Oil Bath Ball Bearing
Suspension rod
Feed Chamber
Detachable cap
Sprinkler arm
Automatic feed Valve for flushing filters
Feed pipe
Ball bearing
Mercury Seal
Wash Out
Pier
Sub drain
Outlet

FIG. 40.



DETAIL SECTION CANDY-WHITTAKER SPRINKLER, SHOWING BALL BEARINGS, MOISTURE PROOF OIL BATH, MERCURY SEAL, ETC.

FIG. 41.

At the Reigate Corporation sewage works is a twenty-four feet diameter bacterial filter bed fitted with a Candy-Caink automatic revolving sprinkler. This distributor consists of a central basin running freely on ball bearings, and to the sides of this basin two tubes (with perforations on opposite sides) are attached, and which are of a length sufficient to reach across the bed. The sewage is delivered to the basin through a trough and then flows into the perforated arms and issues in jets from the perforations therein under a head of from 3in. to 9in. Upon the sewage flowing from the perforations a recoil is set up, causing the apparatus to rotate upon the central pivot of the basin, and thus distributing the liquid uniformly over the whole surface of the bed. Notwithstanding the fact that the Reigate sewage is described as "very strong," and the bacteria bed is only 3ft. 6in. deep, the speed of filtration is 500 gallons per square yard in every twenty-four hours, with a total purification of 96 per cent. on the albuminoid ammonia.

The drawings (Figs. 40 and 41)s how the arrangement generally adopted in fixing the Candy-Whittaker sprinkler and the automatic feed valves for fluctuating flows, and a view of a 60-ft. diameter sprinkler of this make, as in use at Accrington, is given in Fig. 42.

The hydrolytic tank and oxydizing beds of the Hydrolytic Tank Construction Co., Westminster, provides for the removal of detritus, the sedimentation, liquefaction, and removal of sludge from the sewage, and also the upward anaërobic filtration of the tank effluent, all within a covered hydrolytic tank (Fig. 43); also the subsequent oxidation and filtration of the effluent upon special nitros and nitrifying beds (Fig. 44) formed in successive layers separated from each other by spaces, through which a current of air is drawn by a fan, and through which the liquid falls from one layer to another, thus providing the necessary oxygen for the lifework of the aërobic organisms and a means of conveying away the gases produced thereby.

The next illustration (Fig. 45) shows the continuous sewage filter introduced by Mr. F. Stoddart, of Bristol, and as installed at Salisbury, Knowle, Horfield, and elsewhere. This filter is not intended to treat crude sewage, but to oxidise and render imputrescible sewage in which the grosser solids have been broken down or removed by one form or other of tank process. As will be seen, its construction is quite simple, and it is built up between piers to the greatest depth possible on the selected site. The filtering medium is hard burnt furnace or destructor clinker, broken to three inches in size and carefully freed from dust and small pieces by screening in water. The floor of the filter is of concrete, formed quite plain (without channels) with a fall of one in thirty-six from the centre to the collecting channel placed around the exterior.

The patent distributing apparatus is laid over the top of the filter dead level throughout, and consists of a number of narrow sheet-iron gutters arranged at right angles to the supply channel and resting upon its margin and upon suitable support at the distant end. The sewage drips from the underside of this distributor by means of a large number of vertical points as shown, and of which there are about 360 to each square yard of filter.

A filter having an effective area of twenty square yards and a

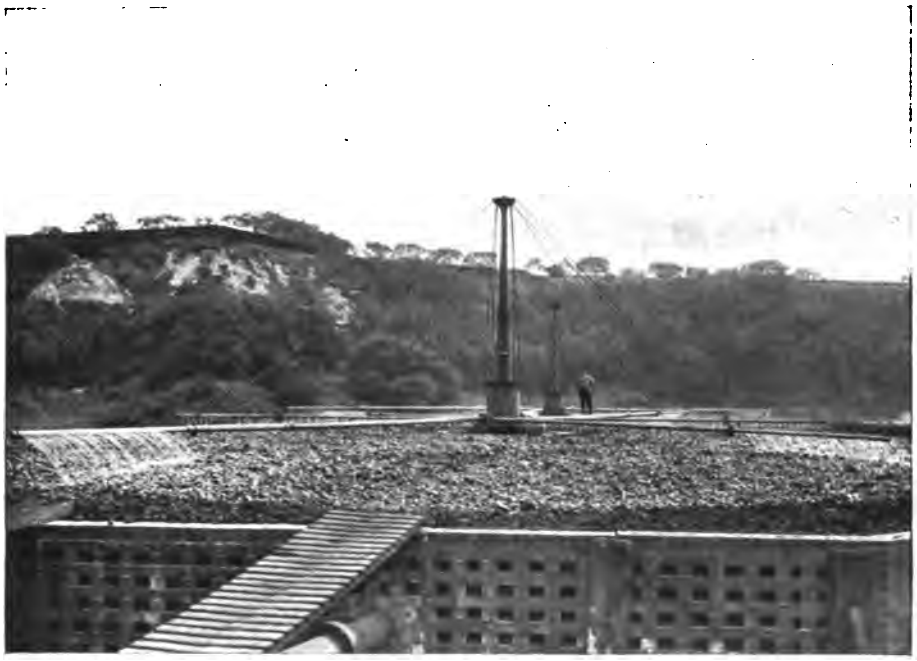
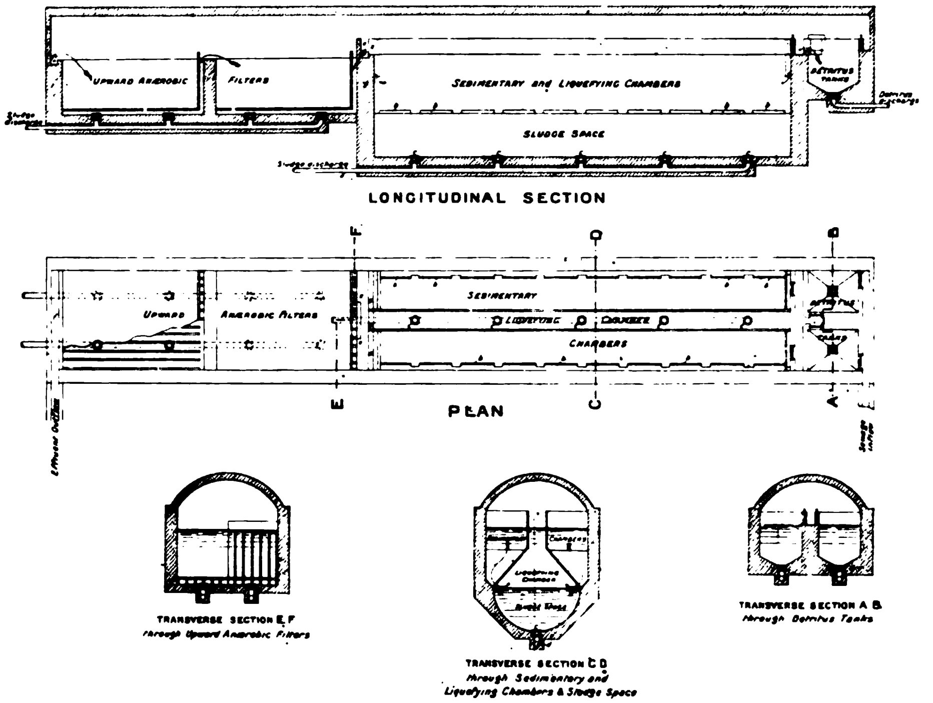


FIG. 42.—60 FEET DIAMETER CANDY-WHITTAKER MERCURY SEALED SPRINKLERS AT ACCRINGTON.



LONGITUDINAL SECTION

PLAN

TRANSVERSE SECTION E F
through Upward Anaerobic Filters

TRANSVERSE SECTION C D
through Sedimentary and Liquefying Chambers & Sludge Space

TRANSVERSE SECTION A B
through Detritus Tanks

FIG. 43.—COVERED HYDROLITIC TANK (HYDROLITIC TANK CONSTRUCTION CO.).

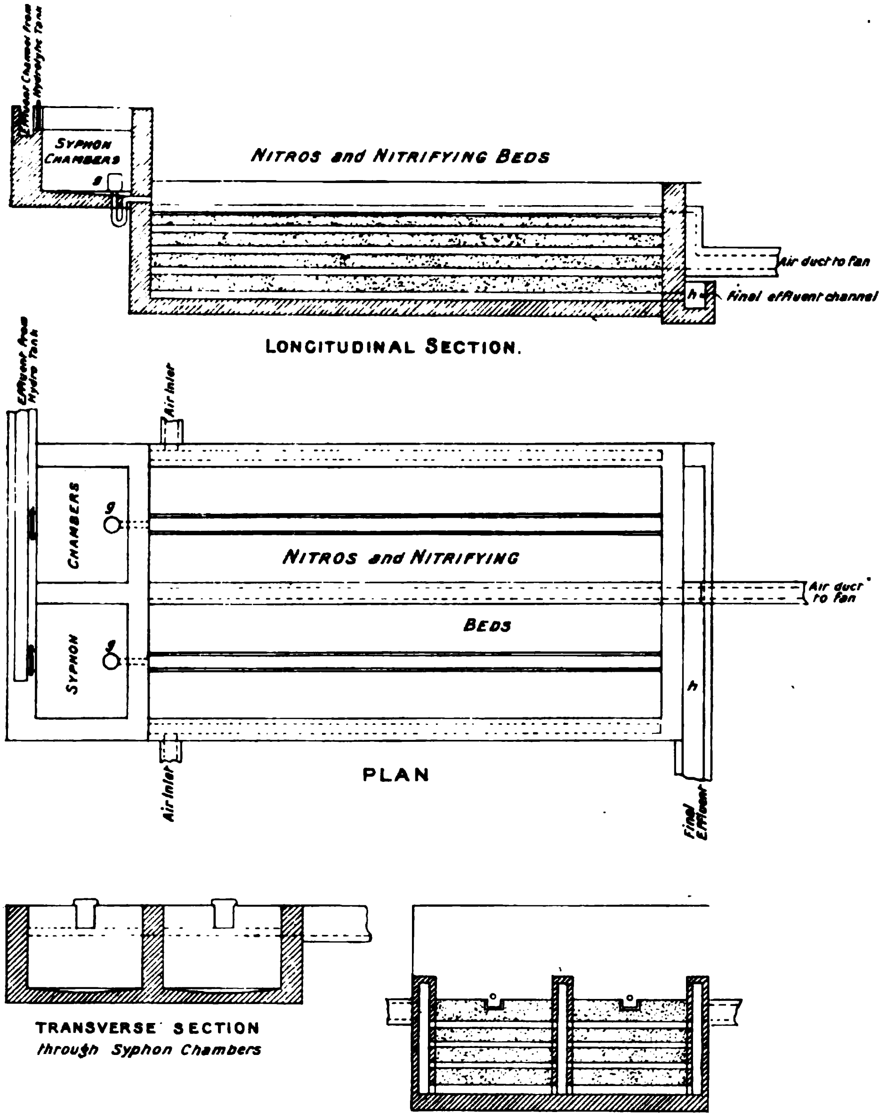
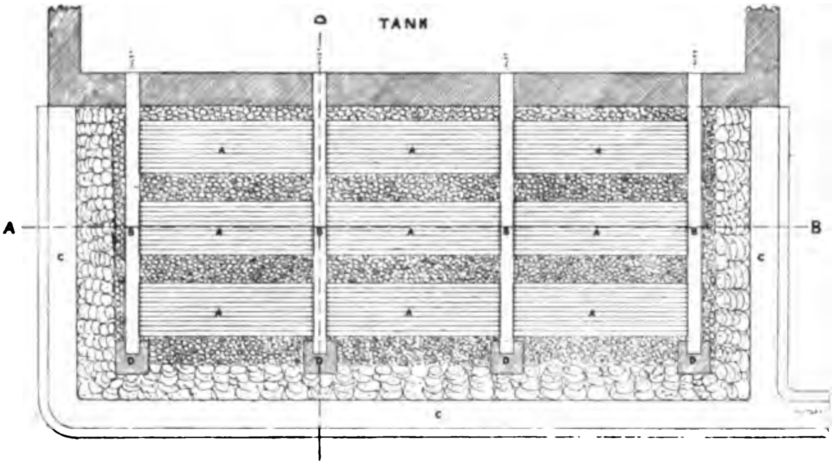
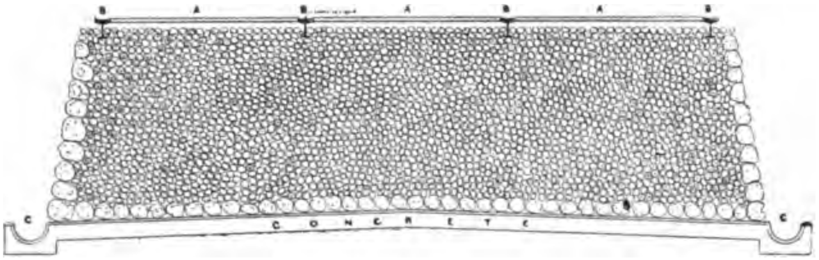


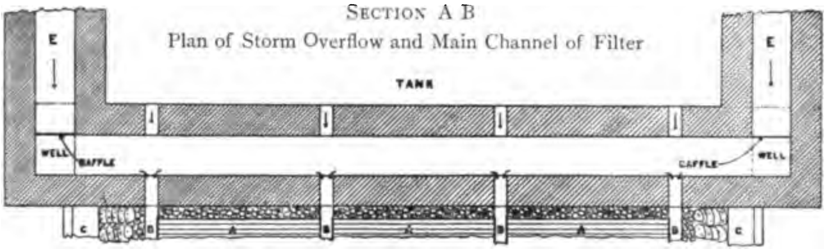
FIG. 44.—NITROS AND NITRIFYING BEDS (HYDROLITIC TANK CONSTRUCTION CO.).



PLAN



SECTION A B


Plan of Storm Overflow and Main Channel of Filter

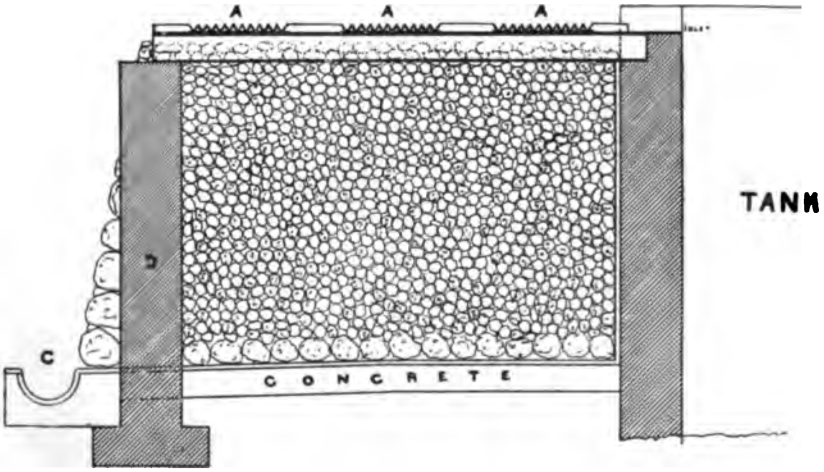


FIG. 45.—EXPLANATORY VIEWS OF STODDART'S FILTERS.

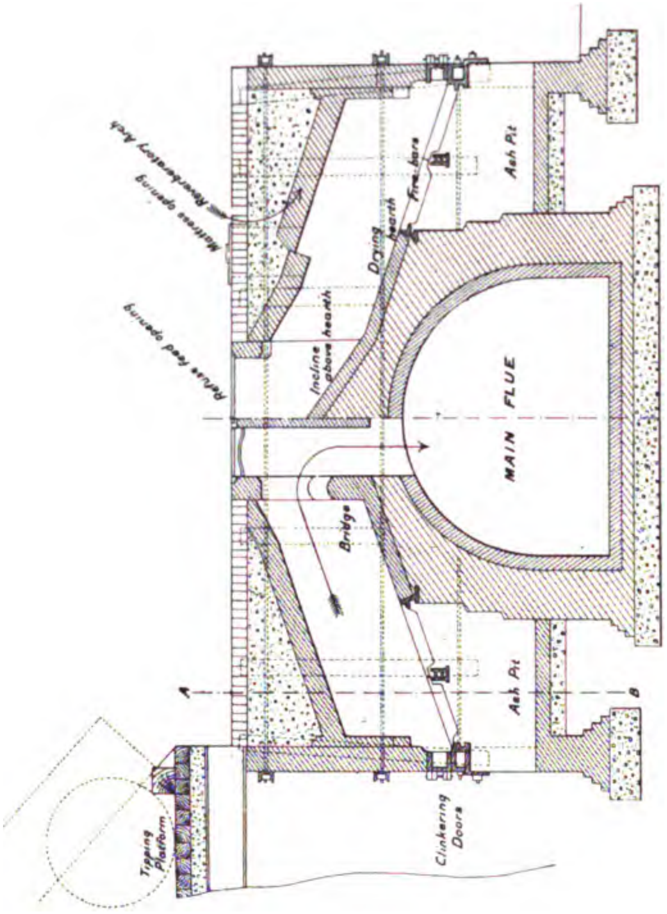


FIG. 46.—FRYER'S DESTRUCTOR (1876).

depth of six feet is capable of dealing with the sewage of 600 persons after having first passed through detritus and sedimentary tanks. The filter is well suited to situations where ample depth is available but surface area limited.

In the " International " or polarite biological system a six-inch layer of " polarite " is mixed with an equal quantity of clinkers in the final bed, and the sewage is distributed upon a continually intermittent system of working by means of the Candy-Caink automatic sprinkler, giving alternately one minute's discharge and three minutes' rest. The sewage is bacteriologically purified to the extent of from ninety-two to ninety-seven times, a chemical purification as high as 97 per cent. has been attained, and an excellent effluent is said to be obtainable when working at the high rate of 1,500 galls. per square yard of area per twenty-four hours. This system is in use at Southwold and Knottingley.

At the Hendon sewage works, near London, may be seen Colonel Ducat's patent aërated bacterial self-acting sewage purifier or filter, which is designed to effect the oxidation of the sewage by arranging it to drip like rain through the beds, the sewage being distributed over the top of the filter by means of patented automatic tipping troughs. Access for air is given at the sides of the filter beds by inclined pipes, and, where sufficient heat is not obtainable from the natural process of decomposition of the sewage, air artificially warmed is supplied to the filter.

One important difficulty experienced in all sewage treatment has been, and still is, the ready adaptation of the treatment to the varying character of the sewage coming in; and it has been often realized that with a sewage changing almost from hour to hour, some means should be at hand by which any such change could be observed and provided for as may be shown to be necessary. In this connexion, Mr. Scott-Moncrieff has recently devised a testing machine for use in the determination of the best treatment of any given sewage, and by means of which the following essential factors may be obtained, viz. (1) The depth of filter necessary to produce the required standard of purity in the effluent; (2) the quantity of air necessary for the life processes of the organisms; (3) the proper rate of flow per unit of filter-bed surface in order to obtain the best results; and (4) the best period of rest between each discharge to prevent gelatinous growths in the filtering material.

The determination of the points named are obviously of considerable importance, inasmuch as the quantity of air has an important relation to the amount of nitrates produced in the effluent, which, by the adoption of proper arrangements, might be increased to a useful percentage, and the fertilizing effect of the effluent greatly improved.

The fact that faith in bacterial methods of sewage treatment is rapidly gaining ground is shown by the great activity prevailing through this country in the construction of new works and the conversion of old ones to this system. Important work in this direction is being done by Birmingham, Leeds, Bradford, Colne, Canterbury, Buxton, Linlithgow, Manchester, Burnley, Batley and a great many other towns. Valuable experimental work has been carried out by the Birmingham Tame and Rea District Drainage Board, which body has now begun to lay down a large installation of bacteria beds and sprinklers. Leeds is further considering the question of taking its sewage some distance away and treating it on land, or else treating it upon bacterial lines at home. Manchester too has carried out a large amount of experimental work, and is now putting down bacteria beds at Davyhulme at a cost of £81,000. Burnley is constructing open septic tanks and secondary bacterial contact beds of an area of twelve acres, at a cost of about £35,000. Installations of the septic tank system have been recently completed at Gosport, Yeovil, Itchen, Marlborough, Morecambe, Sittingbourne, Rodborough, Sidford, and other towns, and many new works are in progress, including installations in Algeria, Australia, Buenos Ayres, Rouen, and at several places in the United States and in South Africa.

A marked feature in recent progress in sewage treatment is the rapid growth in the application of the automatic revolving sprinkler to bacterial filters, and the close attention paid to the question of what further anaërobic treatment of the sewage is necessary upon its delivery at the outfall works from the sewers.

I have now shortly outlined the general position of the question of sewage disposal as it stands in Great Britain at the present day, have noted something of the decided progress that has been made during the past few years, and also referred briefly to some of the leading appliances and systems which have rapidly sprung into existence to meet the new and improved conditions as they have become established by the steady prosecution of scientific inquiry and practical experiment, and I must now proceed to observe the advances made in another important branch of the municipal engineer's work, viz., that of the—

Disposal of the Domestic and Trade Refuse of Towns

ALTHOUGH the developments under this head have not during the past few years been of such a revolutionary character as those reviewed in connexion with the subject last considered, yet, since the birth of the "Refuse Destructor" system some thirty years ago, many very decided improvements and advances have been made. The first "destructor," so styled, was that put down in Manchester about the year 1876 by Mr. Fryer, of Nottingham; and the towns of Birmingham, Leeds and Bradford quickly followed in the adoption of the destructor system of dealing with refuse. Since that date, however, a vast amount of experience has been gained throughout this country in the burning of town refuse and the utilization of heat derived therefrom. The early type of furnaces used were not well designed for the purpose, and engineers and manufacturers have since directed great attention to the production of such a destructor as will properly burn the material to be dealt with without producing a nuisance to the neighbouring inhabitants, and at the same time enable the heat so generated to be turned to practical account. As to what degree of success has been attained in this direction is perhaps best judged from the fact that there are now a considerable number of modern destructor installations in various parts of this country, situated in close proximity to populated centres, which have been working for many years past with full satisfaction to all concerned.

At the present day the importance of the elements of sanitary science are sufficiently well recognized to render it unnecessary to dwell upon the need for the removal and efficient disposal of all refuse matter created by a population, affecting most vitally as it does the health and well-being of the public. Various means of disposal are adopted in different districts, according to local requirements, and these methods it is found necessary to modify from time to time as the town develops and the population increases. The old methods, such, for example, as the tipping of refuse upon hollows or waste land, become exhausted; the cartage or barging of the material to sites at considerable distances from the town boundaries becomes increasingly expensive, besides being at best an insanitary mode of disposal.

In all large centres of population at the present day there appear to be at least two questions of yearly increasing magnitude; one is the removal and sanitary disposal of the town's refuse, and the other the growing need for motive power for the performance of various municipal services, such as lighting, traction, pumping, and other work. In dealing with the refuse of towns on the destructor system, its mere disposal, therefore, is not by any means the only consideration ; a commercial aspect of the subject has developed, which, from its important bearing upon public funds, has of recent years called for the most careful consideration of those responsible for its satisfactory solution. For many years past scientific experts, municipal engineers, and public authorities have been directing their attention to the utilization of refuse as fuel for steam production, and such progress in this direction has been made of late that in many towns its calorific value is now being utilized daily in operating machinery of various kinds and powers.

There is, however, a degree of caution to be observed in the application of refuse fuel to steam-raising purposes, as is well demonstrated by actual experience in its use. At the time when the value of town refuse as a low-class fuel was first recognized, the idea was disseminated that the refuse of a given population was of itself sufficient to develop the necessary steam power for supplying that population with the electric light. The economic importance of a combined destructor and electric undertaking of this character naturally presented a somewhat fascinating stimulus to public authorities, and possibly has had much to do with the recent development, both of the adoption of the principle of dealing with refuse by fire, and also of lighting towns by electricity. However true this aspect of the question may be as the statement of a theoretical scientific fact, experience, so far, has not shown it to be a basis upon which engineers may with safety venture to calculate, although, under certain conditions of equalized load, a well-designed destructor station can be made to perform an important commercial service to an electric or other power-using undertaking.

The primary function of the destructor, however, is, of course, the sanitary disposal of the refuse, whilst every advantage should be taken of the heat generated, in order to form a set-off against the cost of the refuse disposal account. From actual experience with modern refuse destructors it has been ascertained that the calorific value of unscreened house refuse varies from one to two pounds of water evaporated per pound of refuse burned, the exact proportion depending on the quality and condition of the material to be dealt with. If we take the evaporative power of coal at ten pounds of water per pound of coal, this gives for domestic house refuse a value of from one-tenth to one-fifth that of coal. Using the lower value of one-tenth, a year's refuse from a population of about 37,000 people, or about 9,000 tons, would, if so burnt as to fully utilize the heat generated, represent 900 tons of coal, which, at 25*s*. per ton, equals £1,125 per annum—a very fair set-off against the working and capital expenses of such an installation. Or, putting the matter in another form, if we calculate on the same basis of 1 lb. of water evaporated per pound of refuse, this destructor would be capable of generating about 2,300 lb. of steam per hour, which, on the basis of 20 lb. of steam per I.H.P. per hour is equal to 115 I.H.P. continuously throughout the year, day and night. About 14 per cent. of this power would be consumed in driving the forced draught to the furnaces, thus leaving about 100 H.P. available for external work. It will thus be seen that the turning of the heat energy to some useful work in the modern destructor station is a very important factor in the design and economical working of such a plant.

Reference will now be made to the principal types of destructors in use at the present day. In addition to Fryer's slow-combustion furnace already referred to, the following leading types must be mentioned, viz.: Warner's "Perfectus," Horsfall's, Beaman & Deas', Meldrum's "Simplex," Baker's, and the Heenan twin-cell destructor; also may be named Jones' Ealing model, Balls' destructor for small towns, Willoughby's, Mason's, and the "Sterling" destructor.

Fryer's Destructor.—The general arrangement of Fryer's destructor (Manlove, Alliott & Fryer), as patented in 1876, is illustrated in Fig. 46, and has since formed the basis of many later designs. An improved destructor has been erected by Messrs. Manlove, Alliott & Co., at Cobbe Quarry, Liverpool; each cell consumes from twelve to fifteen tons of refuse per day, and the charging is effected by means of Boulnois & Brodie's patent charging apparatus, which consists of two trucks for each cell travelling on rails over the feed holes and into which the charge of refuse may be quickly dropped. This apparatus provides good storage for the refuse, and effects a saving in the cost of handling it. Four water-tube boilers are used with the cells and produce steam at 120 lb. per square inch. The cost of labour for burning is estimated at 8½*d*. per ton. Similar works have been erected at Shoreditch, Cambridge, Whitechapel, and other places. Fig. 47 is a sectional elevation along the front of the cells at the Shoreditch

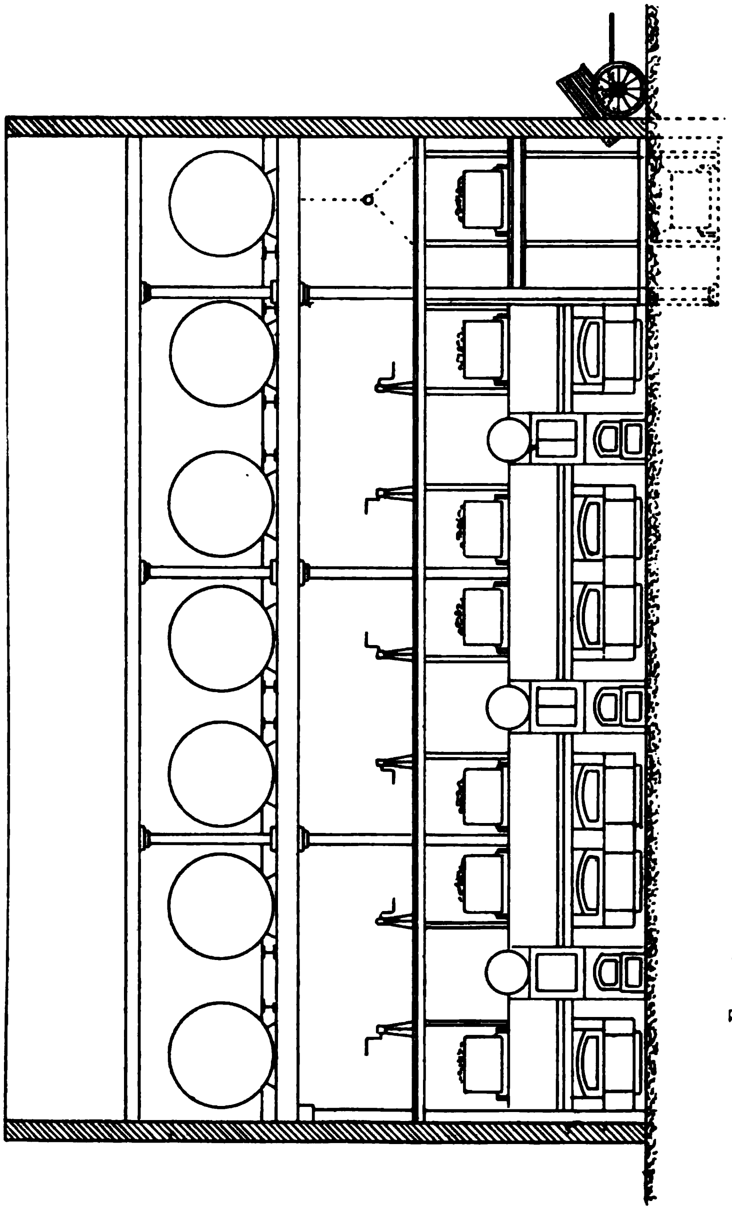


FIG. 47.—SHOREDITCH DESTRUCTOR—SECTIONAL ELEVATION ALONG FRONT OF CELLS.

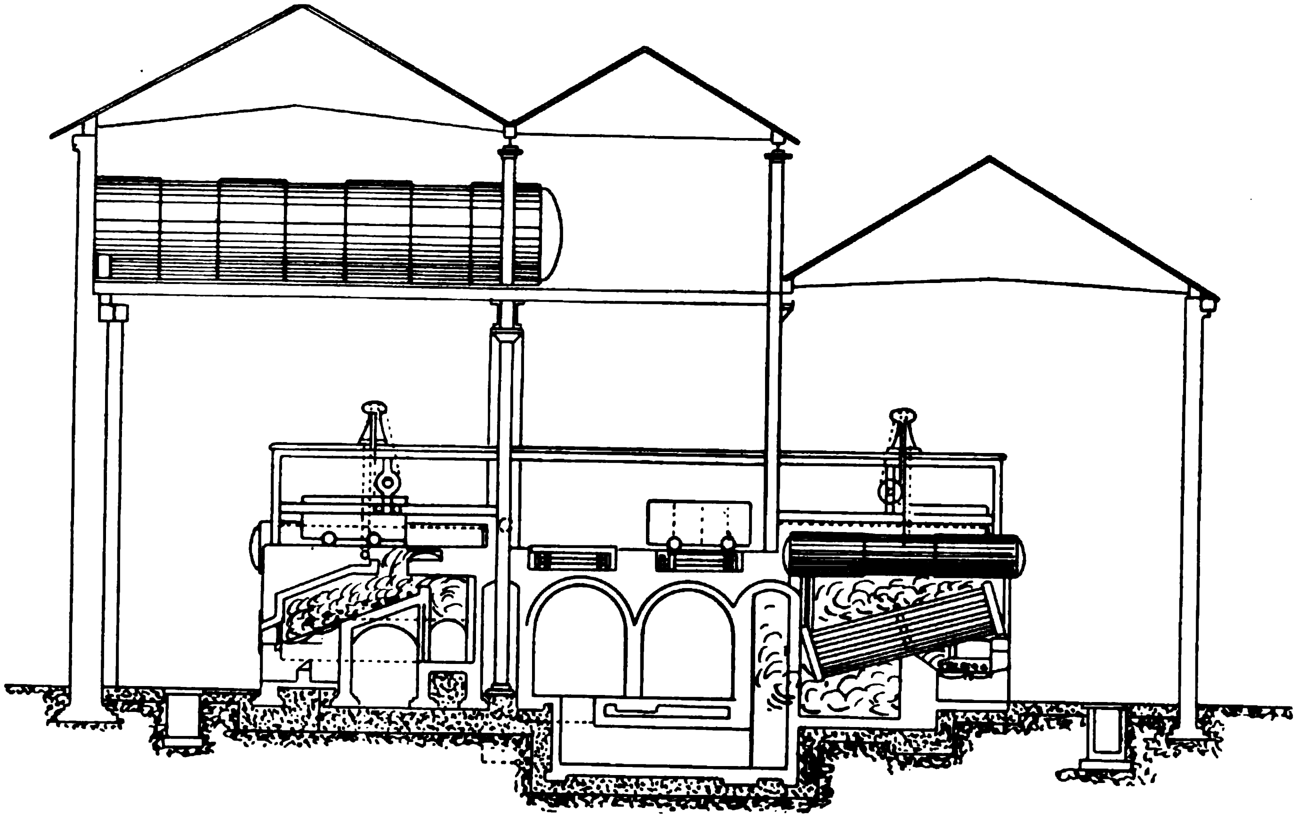


FIG. 48.—SHOREDITCH DESTRUCTOR. CROSS SECTION THROUGH BOILERS, FLUES AND CELLS. (BOILERS BY BABCOCK AND WILCOX.)

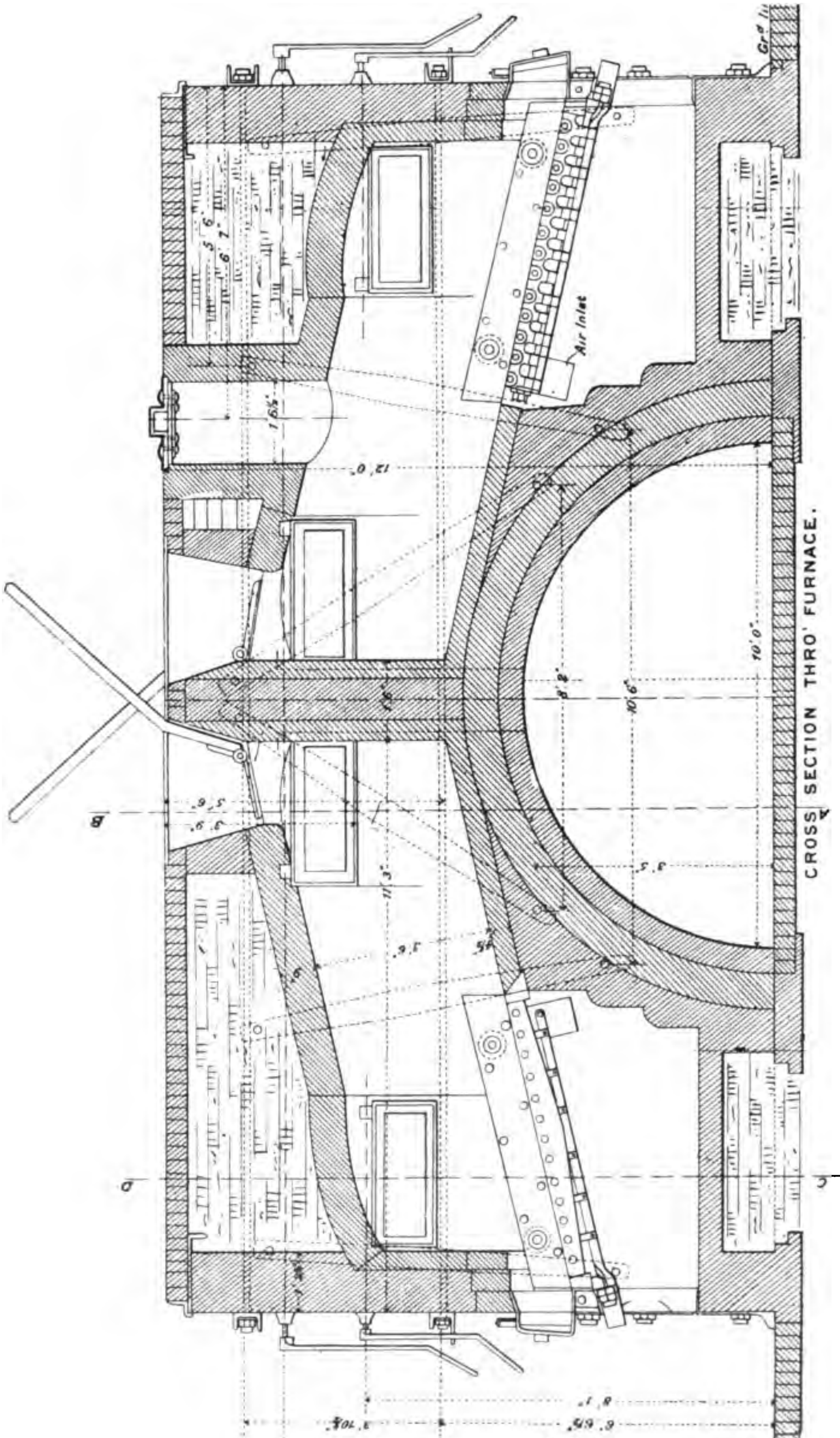


FIG. 49.—WARNER'S "PERFECTUS" DESTRUCTOR (GODDARD, MASSEY AND WARNER).

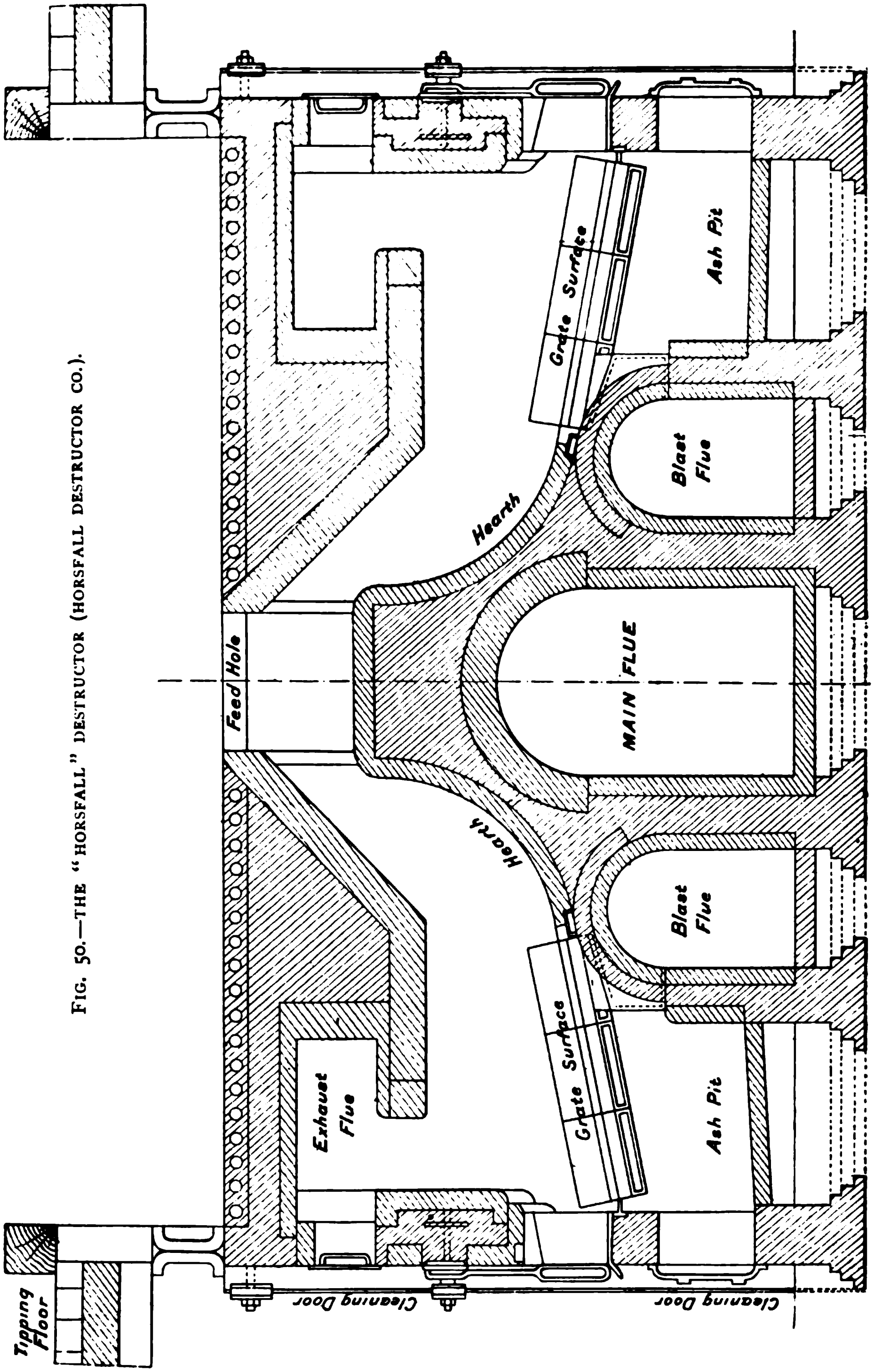


FIG. 50.—THE "HORSFALL" DESTRUCTOR (HORSFALL DESTRUCTOR CO.).

destructor works, and Fig. 48 is a cross-section through the boilers, flues, and cells. The illustrations show the improved Manlove-Alliott destructor fitted with Boulnois & Brodie's charging apparatus, also the Babcock & Wilcox boilers for the utilization of the waste heat, and the large thermal storage cylinders on the top floor for the storage of a part of the energy generated until required to be given out at the time of maximum load in the electricity works.

Warner's "Perfectus" Destructor (Fig. 49) is made by Messrs. Goddard, Massey, & Warner, of Nottingham, and is in use at Hornsey, Bournemouth, Royton, Hyde, Newcastle-on-Tyne, Sheffield, Madras, and elsewhere. The general arrangement of this destructor is somewhat similar to Fryer's, but it also provides special charging hoppers, dampers in the flue, dust-catching arrangements, rocking fire bars, and a modified position of the outlets for the escape of the products of combustion. A tubular boiler is placed close up to the cells and forced draught employed, so that the destructor may be used for steam-raising purposes.

This type of furnace has recently been adopted as being the most suitable for the city of Sydney, N.S.W., after investigation by the City Surveyor.

The Horsfall Destructor, introduced about the year 1887, and since improved from time to time in important details, is a modern high-temperature furnace well adapted for steam-raising purposes; and about 400 cells of this type are in use at some sixty different stations, of an aggregate capacity of nearly 4,000 tons of refuse per day. A few of the largest installations are: Bradford, Brussels, Edinburgh, Hamburg (the largest destructor in the world), Hull, Leeds, Sheffield, and Fulham. A cross section showing the general arrangement of the destructor is given in Fig. 50. The special features include the front exhaust flues in the furnace crown; the cast-iron side boxes, with renewable plates next the furnace; the desiccating hearth over the main flue, and improved sectional cast-iron grate bars.

The following table gives a few instances of the application of the modern Horsfall destructor to steam-raising purposes, and the approximate amount of power generated in each case:—

Plant.	Date of Erection.	No. of cells.	Refuse burnt per 24 hrs. in tons.	Indicated H.P. from Refuse.	Evaporation per pound of Refuse.
Pembroke Co. (Dublin) Electricity Works .	1900	2	18	84	1·21
Stockton-on-Tees (power used for mortar making and clinker crushing) . .	1901	2	23	109	1·22
Salisbury Sewage Works . .	1902	2	25	115	1·23
West Hartlepool Electricity Wks	1901	6	55	265	1·25
Fulham Electricity Works, London	1900	12	125	500	1·3
Accrington Electricity Works .	1900	6	57½	308	1·39
Huddersfield Sewage Works .	1898	2	32	189	1·42
Beckenham Electricity Works .	1900	3	32½	191	1·512

The Fulham destructor has been installed in conjunction with the Borough electric undertaking, and consists of twelve cells and

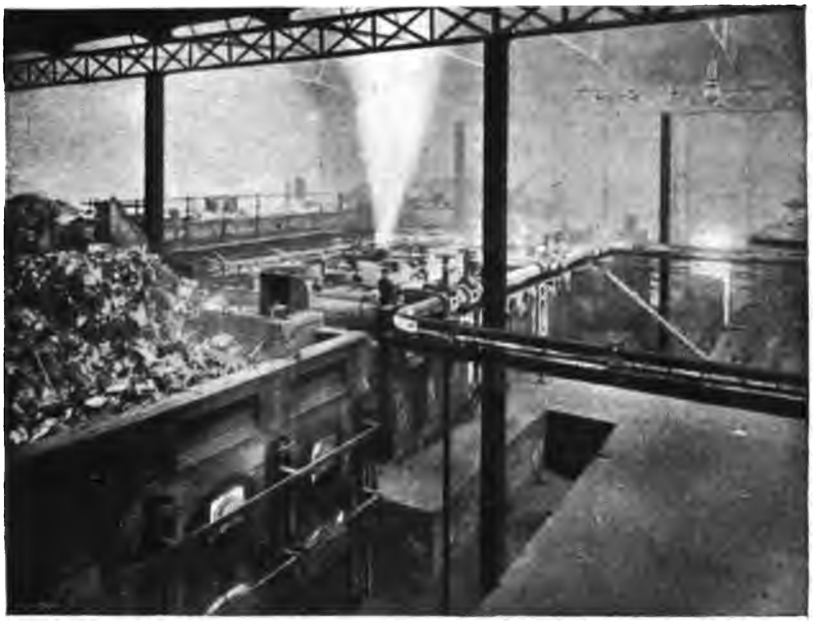


FIG. 51.—FULHAM DESTRUCTOR WORKS. VIEW OF FURNACES, TIPPING FLOOR, BOILERS AND STEAM PIPES.

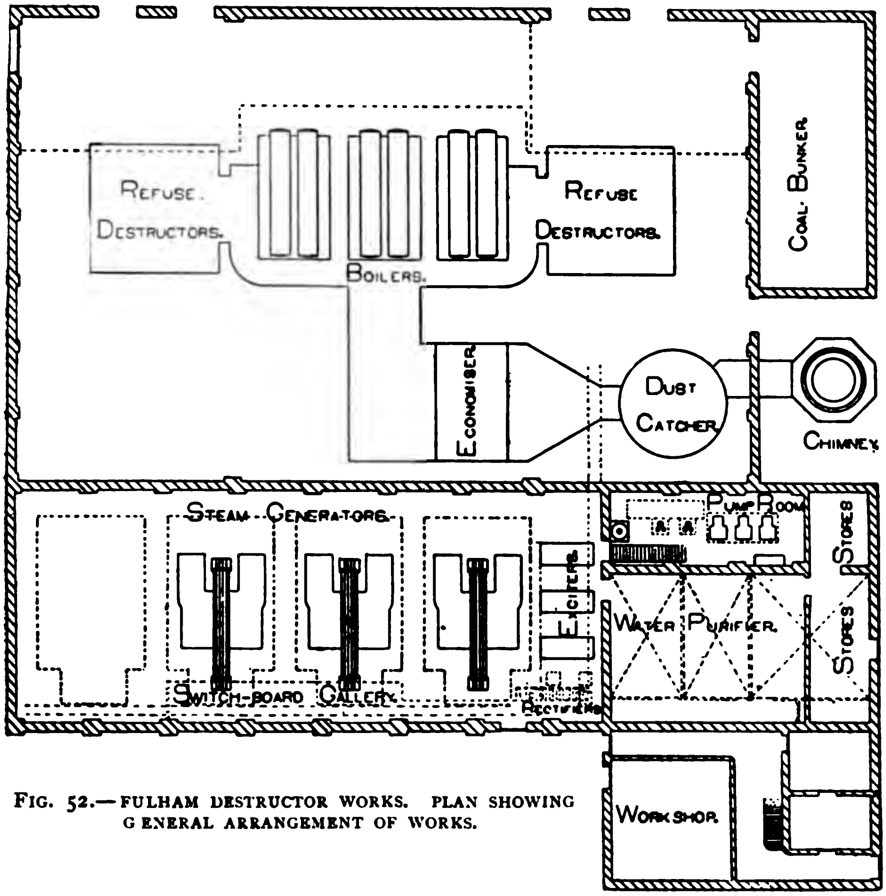


FIG. 52.—FULHAM DESTRUCTOR WORKS. PLAN SHOWING GENERAL ARRANGEMENT OF WORKS.

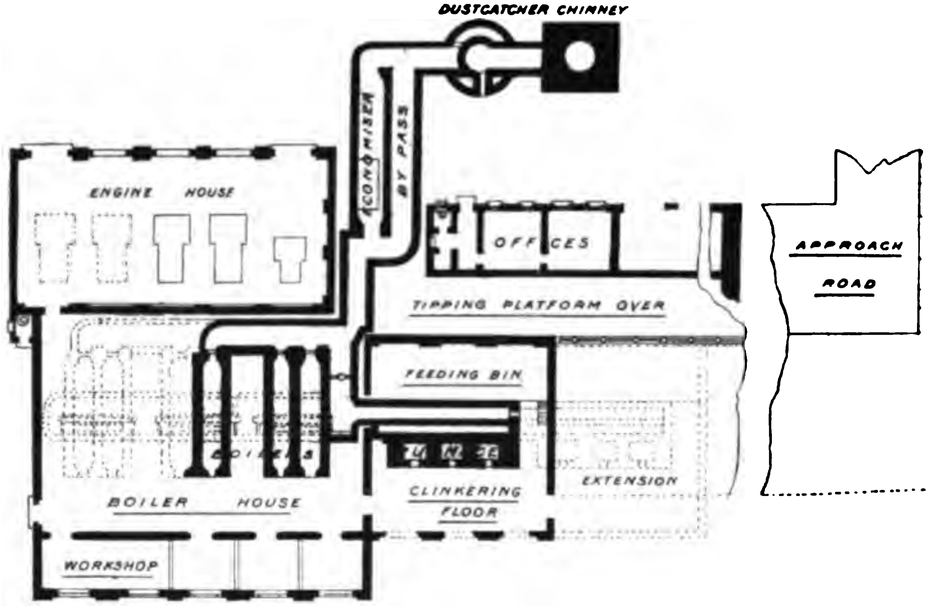


FIG. 53.—PLAN OF BECKENHAM COMBINED DESTRUCTOR AND ELECTRIC LIGHT STATION.

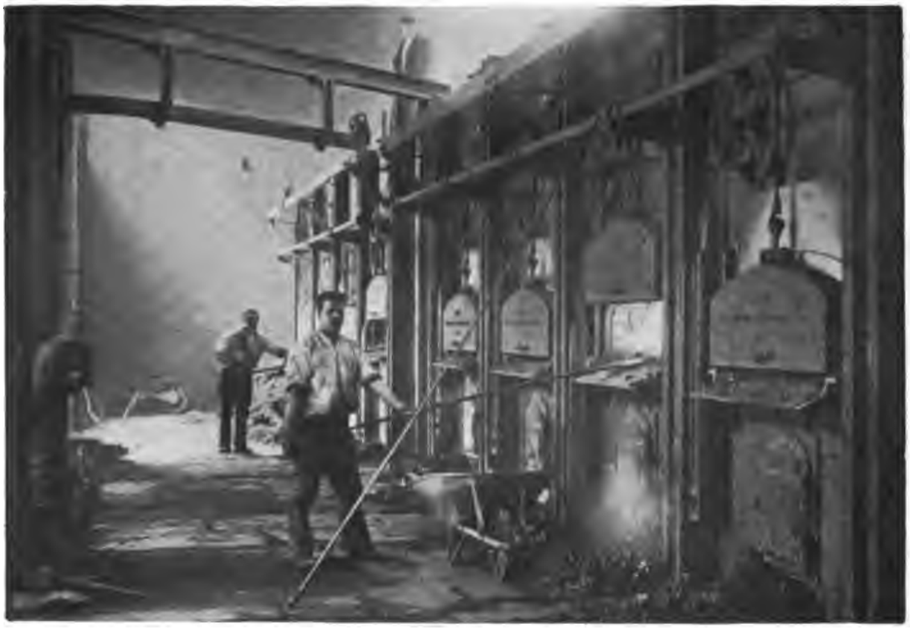


FIG. 54.—VIEW OF FURNACE MOUTHS OF 8 HORSFALL CELLS, WELLINGTON YARD, BOLTON.

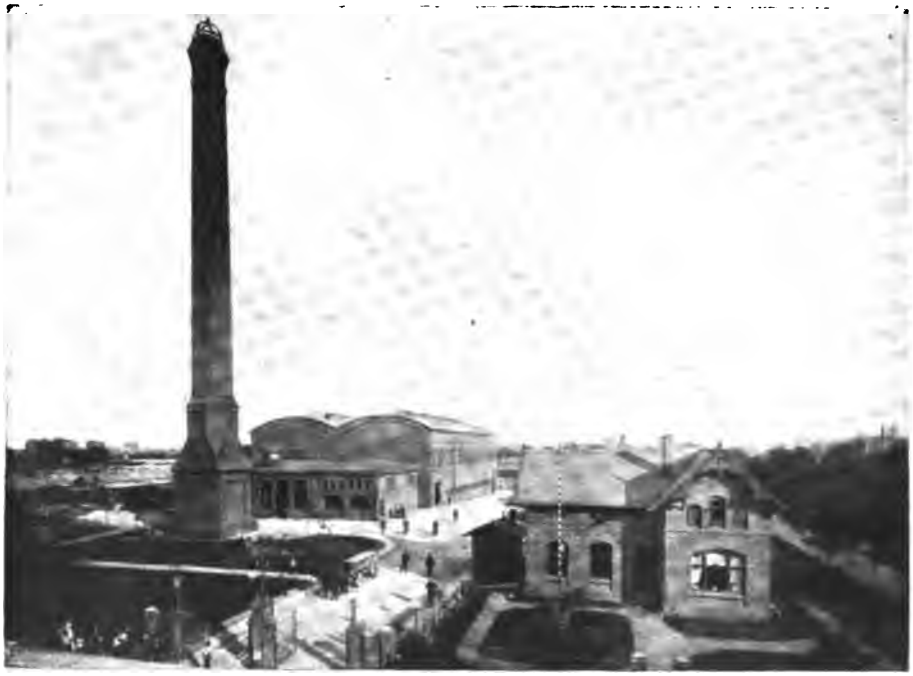


FIG. 55.—HORSFALL DESTRUCTOR AT HAMBURG. THE LARGEST DESTRUCTOR IN THE WORLD.

temperature combustion chamber placed between the cell proper and the main flue, and a powerful forced draught. At Leyton a battery of eight cells deals with the house refuse and filter-press sewage sludge from a population of over 100,000 persons at the rate of about seventeen tons of the mixture per cell per twenty-four hours. Steam is generated in Babcock & Wilcox boilers, and is used for pumping low-level sewage and driving other machinery at the sewage works. At Canterbury a combined destructor and electric undertaking on this principle has been put down, and, according to the test of the City Surveyor, the evaporation from the destructor was at the rate of 4,717 lb. of water per hour, equal to about 235 indicated horse power.

The Meldrum Destructor. During the past five years Messrs. Meldrum Bros. have erected over fifty destructors, and this year nearly all contracts have been placed to utilize the power for electrical undertakings—a circumstance which may be taken as indicating the prominence this aspect of the question of refuse disposal has now assumed, and the appreciation which the practical utility of the surplus heat from destructors has attained. The Meldrum furnace (Fig. 58) is capable of giving good steam-raising results, and is in operation at Rochdale, Darwen, Hereford, Nelson, and very many other places. The general design of the destructor differs widely from any of the foregoing and is practically one long cell, fed and clinkered at four or five different furnace mouths, according to the number of grates installed and by this means an approximately uniform temperature is maintained throughout. The grate areas are arranged side by side

Plan of general arrangement of an 8 cell Beaman & Deas destructor as installed at Leyton.

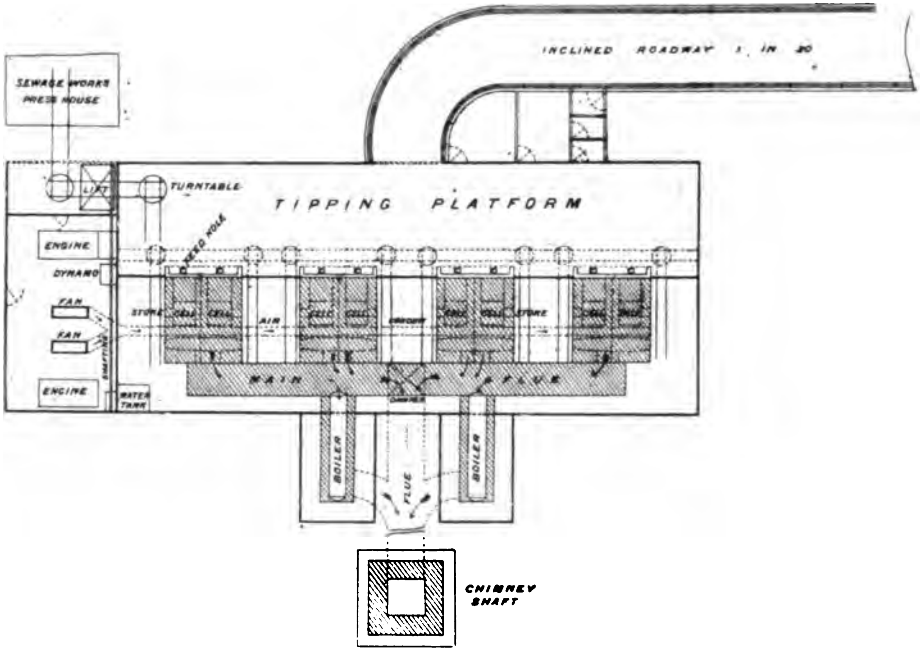
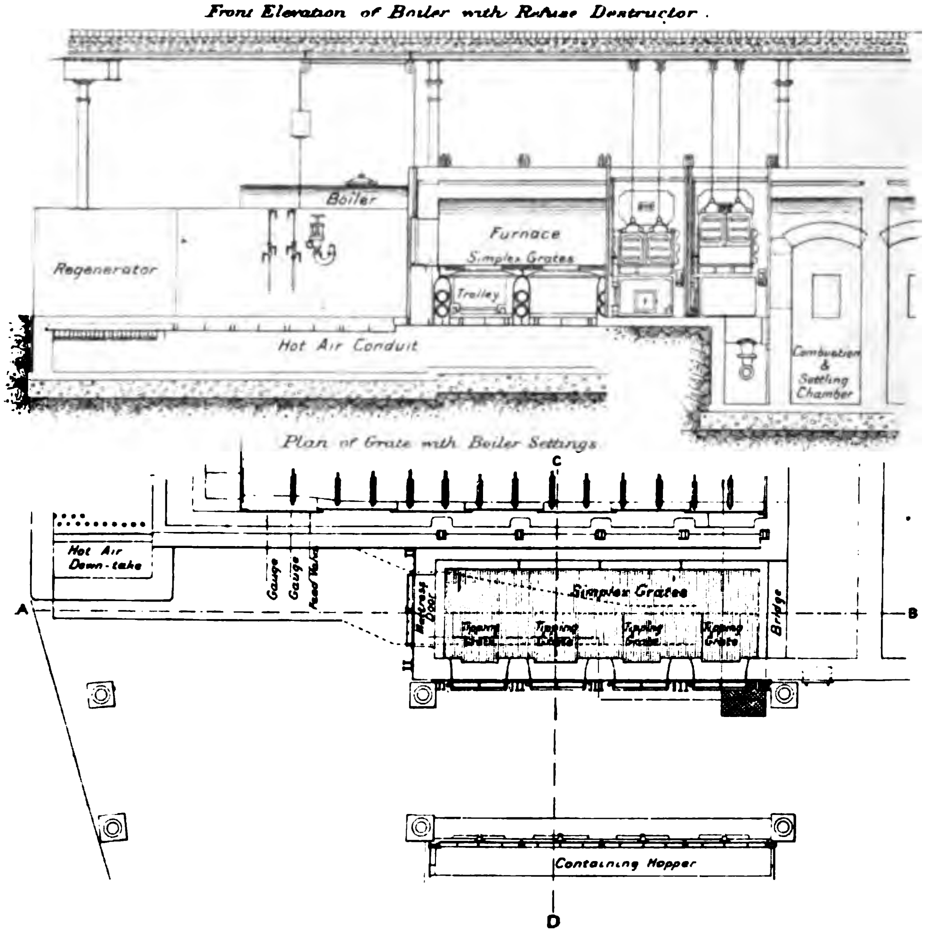


FIG. 57.—LEYTON DESTRUCTOR.



Front Elevation of Boiler with Refuse Destructor.

Plan of Grate with Boiler Settings

FIG. 58.—THE "MELDRUM" REFUSE DESTRUCTOR (MELDRUM BROS., LTD.).

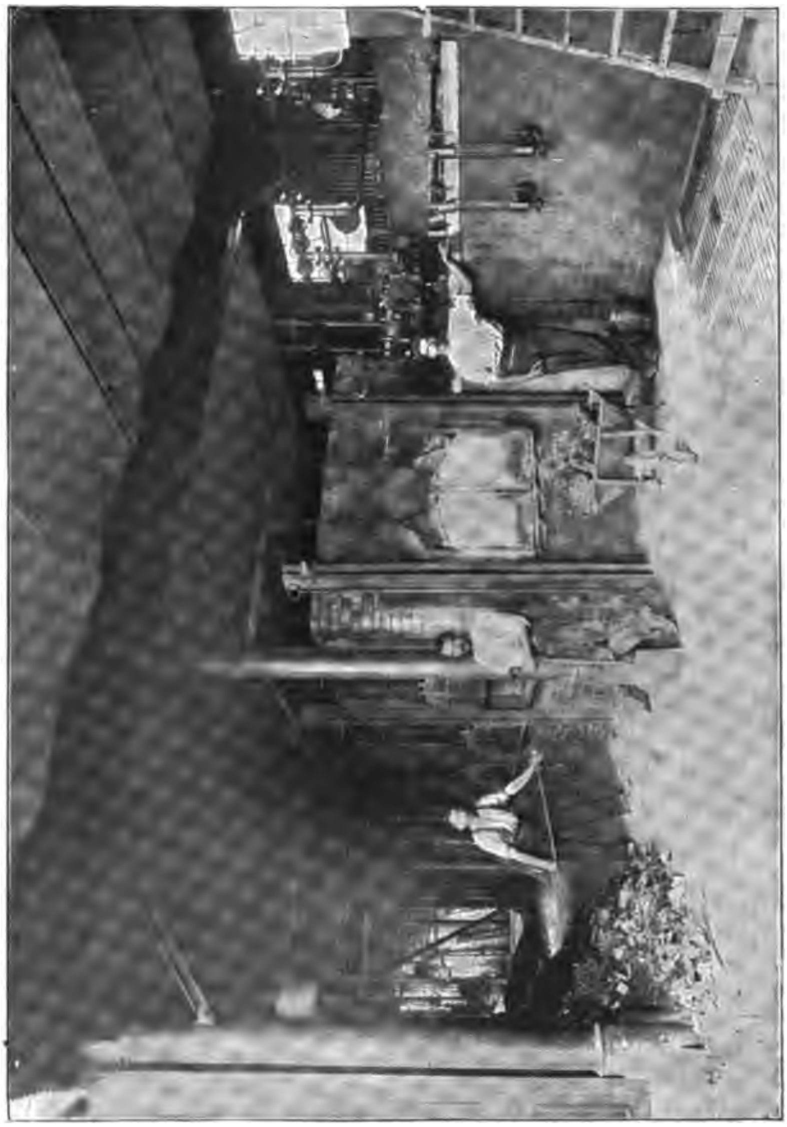


FIG. 59.—VIEW OF DESTRUCTOR HOUSE AT DARWEN (MELDRUM BROS., LTD.).

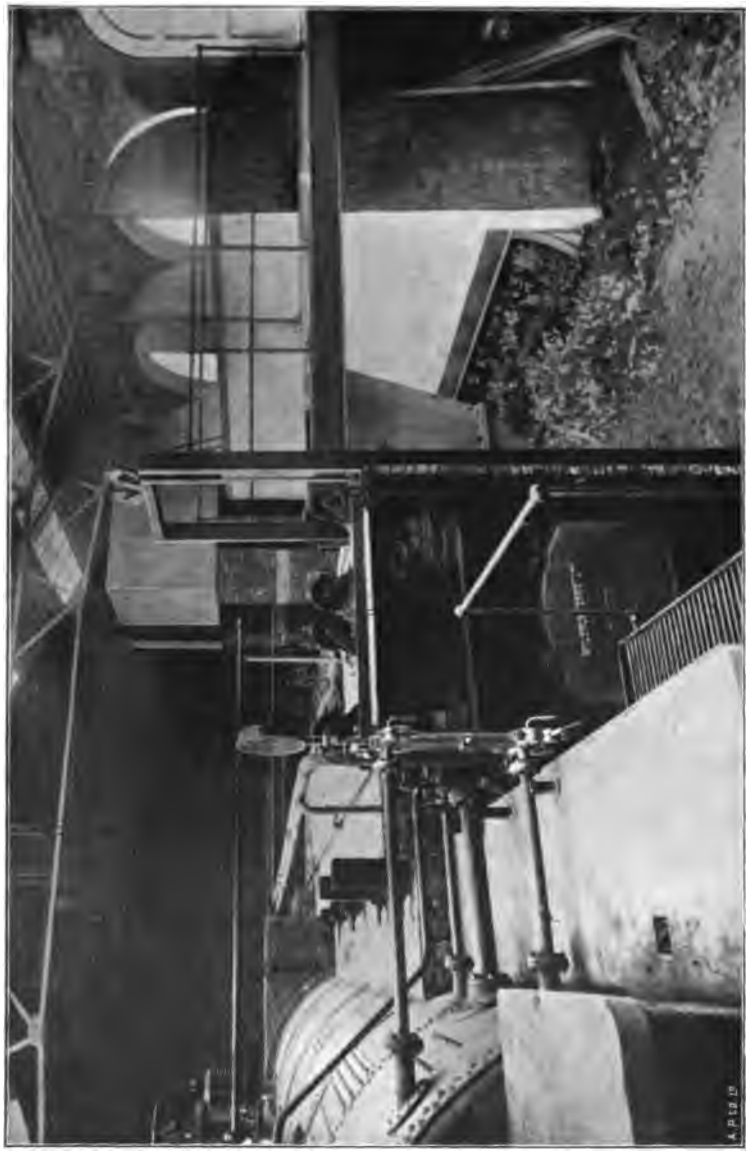


FIG. 60.—GENERAL VIEW OF DESTRUCTOR AT NELSON (MELDRUM BROS., LTD.).

and are separated only by dead plates. The ashpit, however, is divided into sections corresponding to the grate areas, in order to localize the forced draught. Each section is closed air-tight by a cast-iron plate, and there is an air-tight door for the removal of fine ash. The destructor is fitted with the Meldrum steam jet blowers, and in which only about 14 to 15 per cent. of the total steam generated is used. It will be instructive to note that at Shoreditch the electrically driven air fans also absorb 14 per cent. of the current produced. The illustration already given represents the destructor as constructed at Darwen, where it is run in conjunction with an electric lighting and power station. A view of the Destructor House is given in Fig. 59. A destructor of the Meldrum regenerative type was erected at Nelson in 1900, the steam from which is to be used in connexion with electric lighting and traction works. A general view of the destructor is given in Fig. 60, and a view of the range of cells and offal hopper in Fig. 61. The calorific value of Nelson refuse is proved to be from one-seventh to one-fifth that of coal, and for steam raising purposes is worth about 2*s.* 6*d.* per ton in that town. The cost of burning the refuse, including capital charges, amounts to 2*s.* 5*d.* per ton.

At Burnley, a Meldrum destructor is generating between 300 and 400 horse power continuously for electric-light purposes. A steam pressure of about 130 lb. is maintained, and over a month's ordinary work an evaporation of 1·5 lb. of water per pound of refuse was obtained. The cost of labour was 10·6*d.* per ton, including the handling of all garbage, offal, etc.

At Sheerness a destructor of this type has been successfully working for some months past in connexion with the waterworks pumping station, occupying a central position in the town, and which thus derives its power (about 70 h. p.) from the refuse of the district. A considerable saving has been thus effected, both in the coal bill and in the cost of cartage to a more distant site. A Meldrum destructor is also working in conjunction with the waterworks of the Hunstanton Urban District Council.

The following brief table gives a few practical steam power results realized by the Beaman & Deas and the Meldrum furnaces at the stations named.

Town.	Make of Furnace.	Water evaporated per hour.	Approximate I.H.P. developed per hour at 20 lb. steam.	Water evaporated per lb. of Refuse (Actual).	Average steam pressure.
		lb.		lb.	lb.
Canterbury .	Beaman & Deas.	4717	235	1·4	132
St. Helens .	Do.	6575	328	1·27	132
Darwen . .	Meldrum	6129	306	1·39	195
Hereford . .	Do.	2980	149	1·51	70·92
Rochdale . .	Do.	7290	364	1·47	113
Nelson . .	Do.	4490	224	1·54	120

Baker's Destructor is of recent design, and Fig. 62 illustrates the latest model of this type. It will be seen that the drying hearth is built over the furnace proper, and the moisture and gases from the drying refuse are withdrawn from this chamber by the forced draught fan and driven with the air supply into the ashpit and through the fire-grate. A two-cell plant of this make has been erected for the Clerkenwell Vestry at Phoenix Wharf, Lambeth, S.E. The

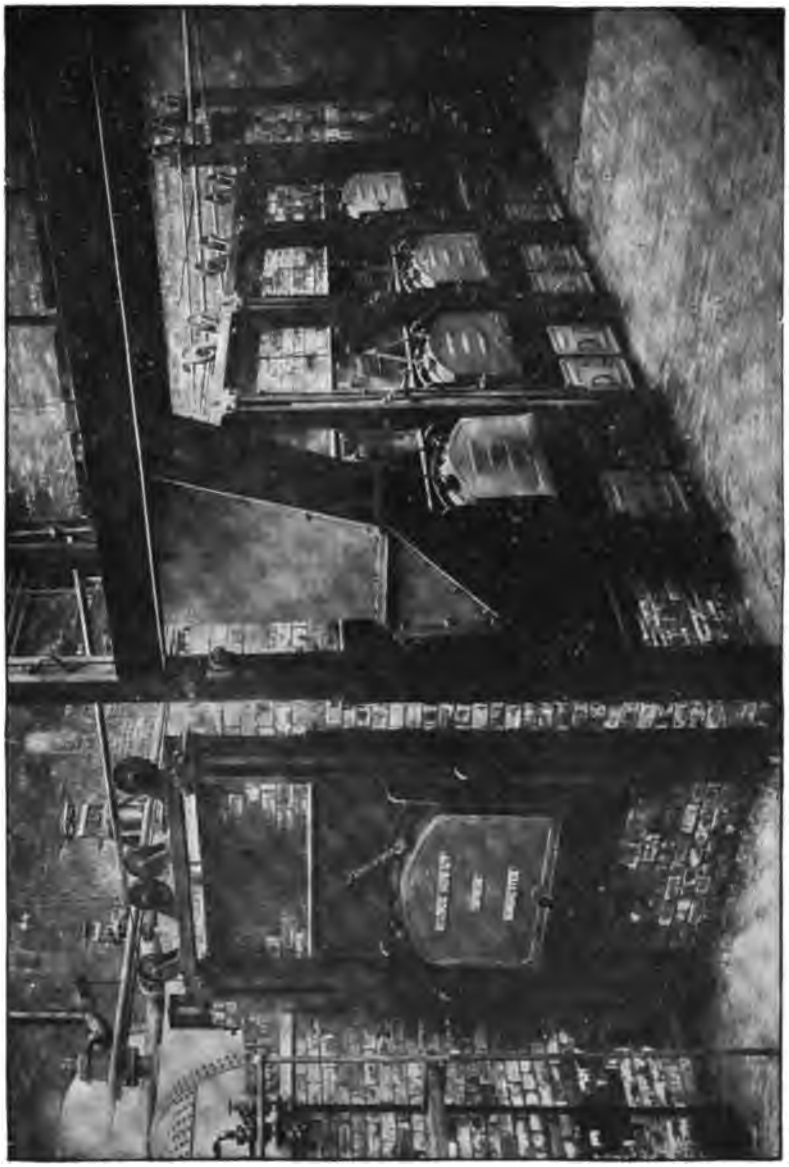


FIG. 61.—NELSON DESTRUCTOR (MELDRUM BROS., LTD.). VIEW OF THE RANGE OF CELLS AND OFFAL HOPPER.

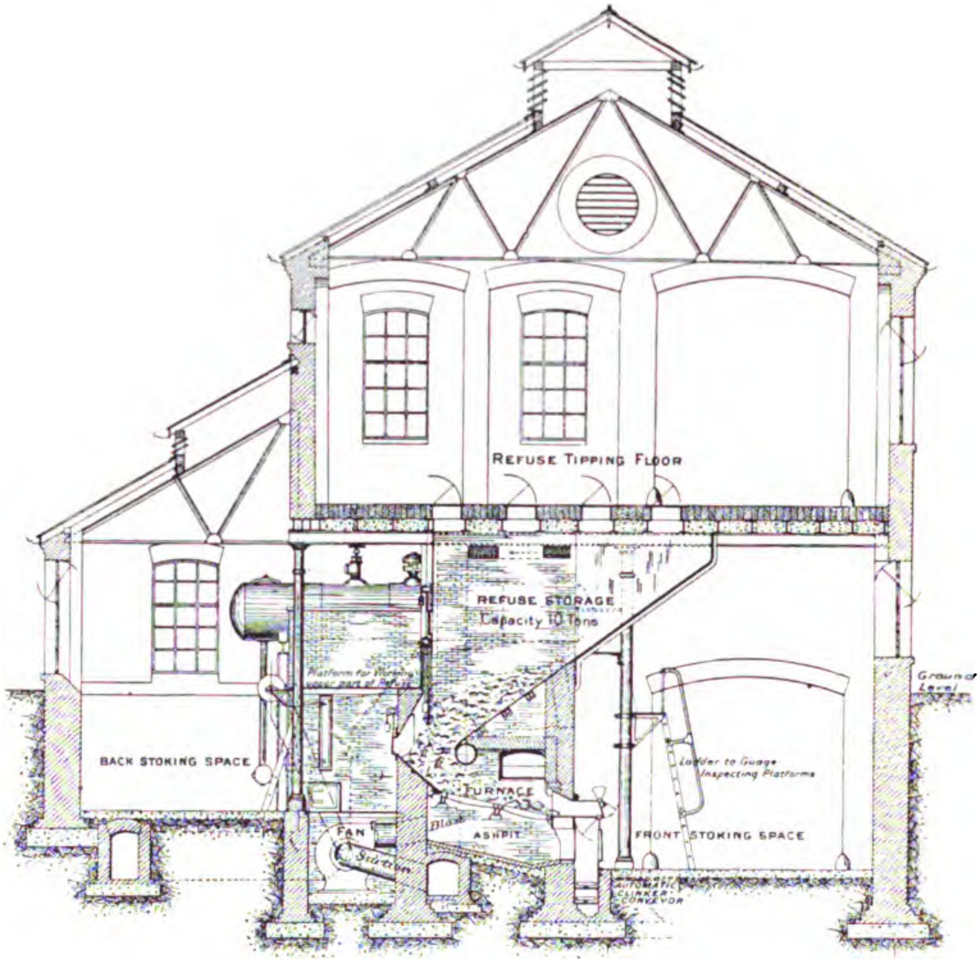


FIG. 62.—BAKER'S REFUSE DESTRUCTOR.

destructor is manufactured by Messrs. Joseph Baker & Sons, Ltd., of Willesden Junction, London.

A destructor of the *Heenan Twin-Cell Type* has been erected at Farnworth, by Messrs. Heenan & Froude, and a larger installation of the same class has now been at work for over 12 months at Gloucester.

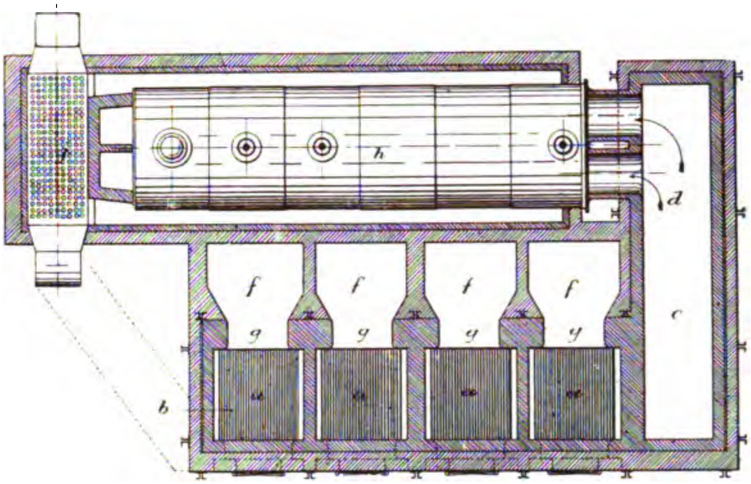
The Gloucester plant consists of two twin-cells. A twin-cell consists of two grates, each 39 sq. ft. area, or 78 sq. ft. for the two, with a fire bridge between them. Each pair of cells is worked together, and is capable of cremating 25 tons of refuse per 24 hours. The guarantee is for the clinker not to exceed 25 per cent. of the refuse. There are two Babcock and Wilcox boilers mounted on the top of the cells, one over each pair, and the weight of water evaporated from and at 212° F. per pound of refuse burned is from 1·25 lbs. to 2 lbs. The working temperature of the furnaces is over 2,000°, that of the flues before the boilers from 1,400° to 1,800°, and of the flues after the boilers from 400° to 700°. The heating surface of the boilers is 1,300 sq. feet each, and the evaporating capacity 4,000 lbs. of water per hour. The forced draft is produced by an electric fan of 12 B.H.P., running at 950 revolutions per minute. The feeding to the cells is done through a shoot at the back of the furnace, and the clinkering from the front of the furnace. The cost of the destructor was about £4,150. About 125 horse power is obtained from the refuse, burning 150 tons per week, and the steam power derived has hitherto been used during the day time for charging the accumulator batteries, but when the electric trams are completed full use will be made of all the power obtainable from the destructor boilers. On the destructor two men are required for each shift, with the assistance of an extra man in the morning, when the refuse is being delivered faster than usual.

Figs. 63 and 64 show the arrangement in plan and section of the "Heenan" patent standard refuse destructor and water-tube boiler, and Fig. 65 illustrates a modified design, suitable where space is limited.

It is now the practice of this firm to construct their furnace arches in such a manner as to cause an undulating motion of the gases as they pass through the furnaces or cells. This is done by forming the arches with their axes at right angles to the direction in which the gases travel (see Fig. 64). With furnaces constructed in this manner a thorough mixing of the gases in the furnaces is ensured, and better combustion and higher and steadier temperatures are obtained.

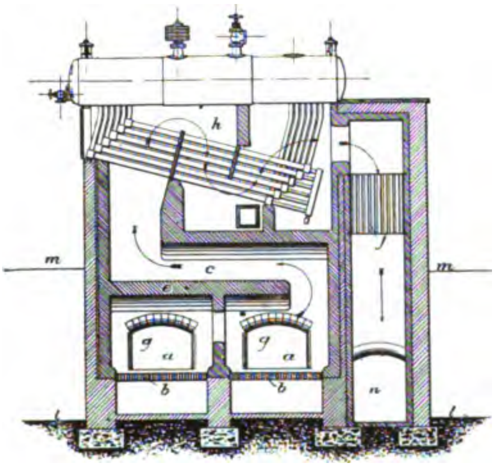
Installations with such furnaces are in operation in many places. Tabulated results of tests made at some of these Plants are given in the Table on page 105. About 30 installations (totalling over 100 cells) have been erected or are in course of erection by Messrs. Heenan & Froude, Ltd., in Great Britain, Ireland, Europe, India and South America, during the last three years.

In the modern destructor station a variety of accessory plant is now employed, including overhead railways for the removal of clinker, clinker utilization plant, hydraulic presses for flag making, patent centrifugal dust catchers, solder extraction furnaces, hydraulic or electric lifts, charging tank apparatus, travelling cranes, boilers, econo-



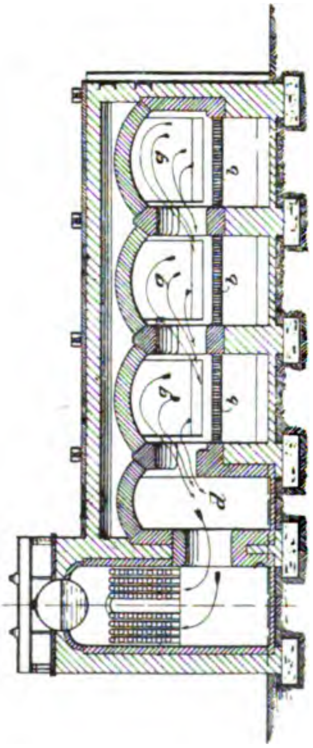
Heenan 'Twin Cell' Refuse Destructor with Lancashire Boiler

FIG. 63



'Twin Cell' Refuse Destructor with Heenan Water Tube Boiler

FIG. 65



'Heenan' Refuse Destructor

FIG. 64

a. Furnaces.
b. Furnace grates.
c. Flue.
d. Combustion chamber.

e. Furnace arch.
g. Refuse feed openings.
h. Water-tube boiler.
j. Regenerative apparatus.

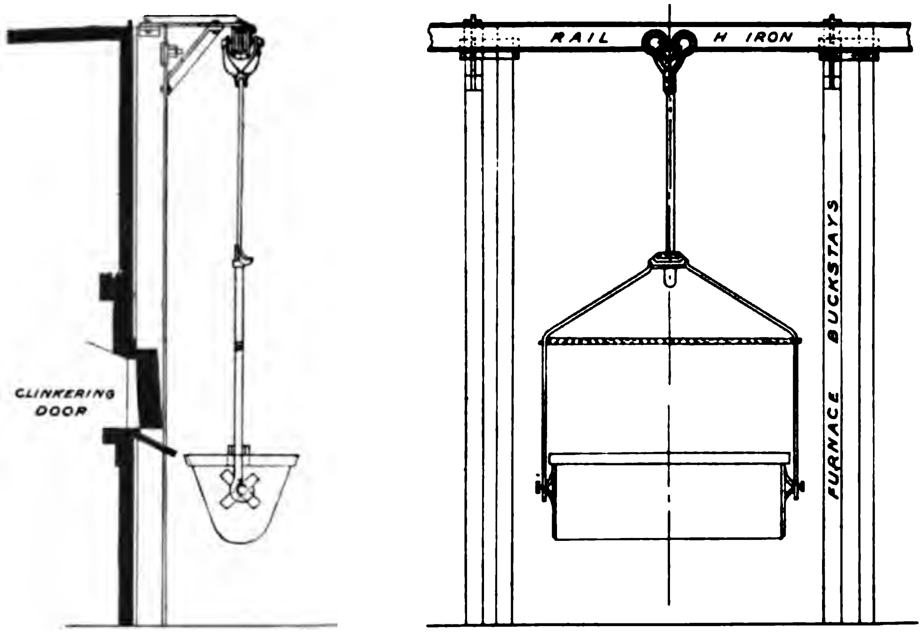


FIG. 66.—COX AND MACTAGGART'S CLINKER OVERHEAD RAILWAY (HORSFALL CO.).

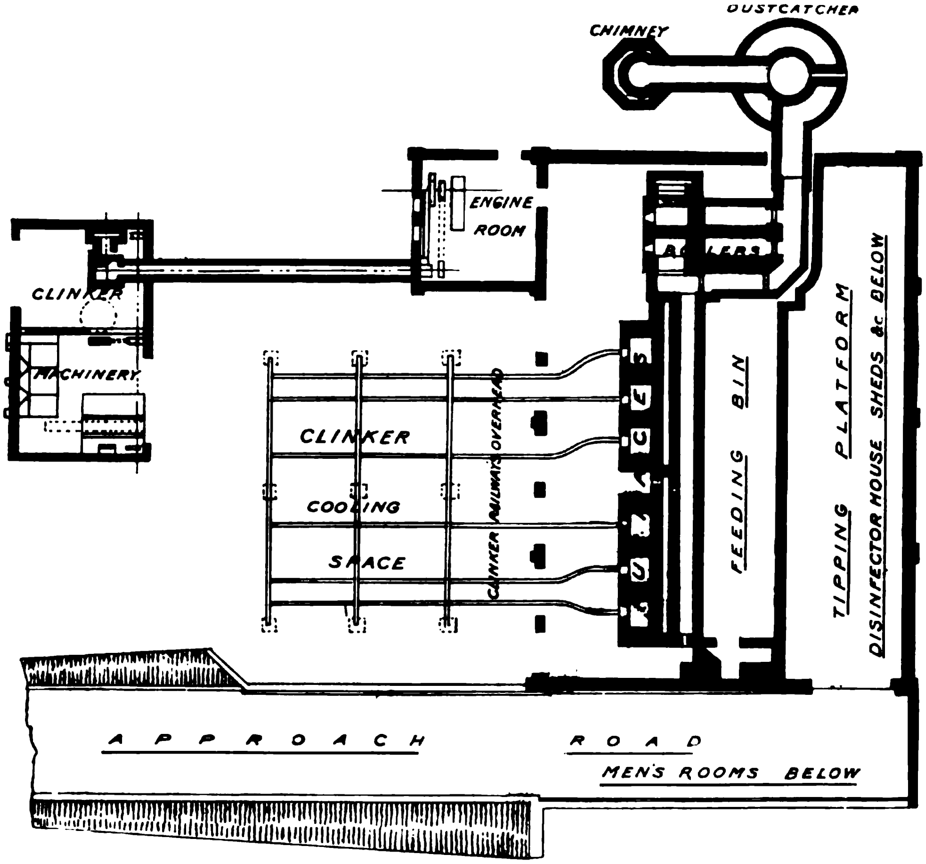


FIG. 67.—COX AND MAC TAGGART'S CLINKER RAILWAY AT MOSS SIDE DESTRUCTOR.

RESULTS FROM "HEENAN" REFUSE DESTRUCTORS.

NAME OF TOWN.	Date of Test.	No. of Cells.	Refuse burnt per 24 hours.	Number and Type of Boilers.	Average Evaporation per hour with feed at 212° F.	Evaporation per lb. of Refuse.	Purposes for which Steam is used.	Average I.H.P. obtained at 20 lbs. per I.H.P.	Approximate cost of Installation.
Barrow-in-Furness	16/12/03	4	42 Tons	One 30·0 × 8·0 dia. Lancashire	5,785 lbs.	1·5	Generating Electricity	289	£4,300 (Plant only)
Northampton	18/11/03	8	88 Tons	Two 30′·0 × 8′·0 dia. Lancashire	10,675 lbs.	1·3	do.	533	£9,700 (including Building Chimney, Inclined Road, etc.)
Mansfield .	17/6/04	4	52·25 Tons	Two Water Tube	8,500 lbs.	1·8	do.	425	£5,600 (Plant only)
Wakefield .	1/1/04	2	30 Tons	One 28′·0 × 7′·6″ Lancashire	5,600 lbs.	2·0	do.	280	£2,600 (Plant only)

misers, super-heaters, and other plant. Fig. 66 shows Cox & McTaggart's patent clinker overhead railway for the removal of furnace clinker, similar to that in use at the Fulham destructor, and Fig. 67 illustrates the arrangement of the same in plan as installed at the Horsfall six-cell destructor, Moss Side, Manchester; Fig. 68 shows Horsfall's arrangement of clinker crushing machinery, and Figs. 69 and 70 illustrate patent clinker brickmaking plant and slabmaking machinery, both as manufactured by Messrs. C. & A. Musker, Ltd., of Liverpool. The Babcock & Wilcox boiler, now so largely used in connexion with destructor steam-raising plants, is shown in Figs. 48 and 56, and Green's economiser for heating the boiler feed by means of waste flue gases in Fig. 71. Fielding & Platt's patent concrete slab hydraulic machinery, as used by the Oldham Corporation in the utilization of the clinker at the Hollinwood destructor depôt for making paving slabs, is shown in Fig. 72, and a view of the press room at Withington Urban District Council's destructor works, near Manchester, is given in Fig. 73.

In conclusion, it may be said that the problem of the disposal of refuse by fire as it exists in Great Britain to-day is one which has been well thought out, and the furnaces and plant of the best makers have been carefully designed and adapted as the result of practical experience, for the work and objects to be attained. The refuse is thus reduced in the most sanitary manner to a minimum of clinker residue without giving rise to nuisance or inconvenience to the neighbouring population, the heat generated is economised to the fullest extent and put to many useful

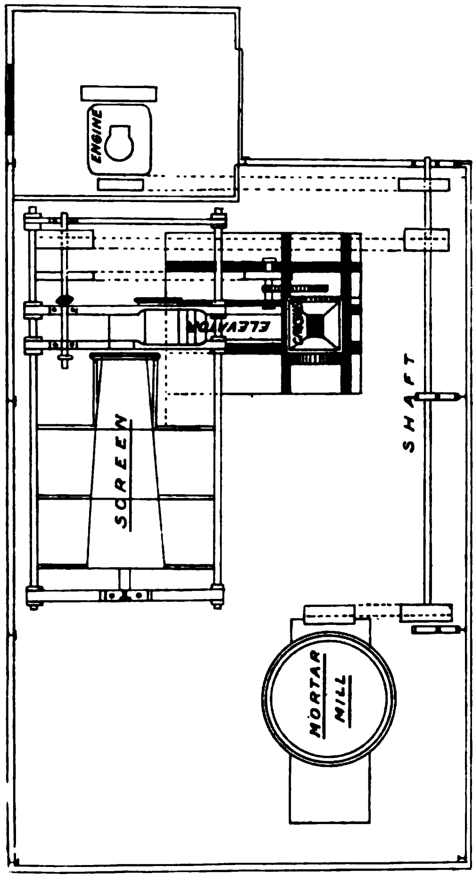


FIG. 68.—CLINKER CRUSHING MACHINERY (HORSFALL CO.).

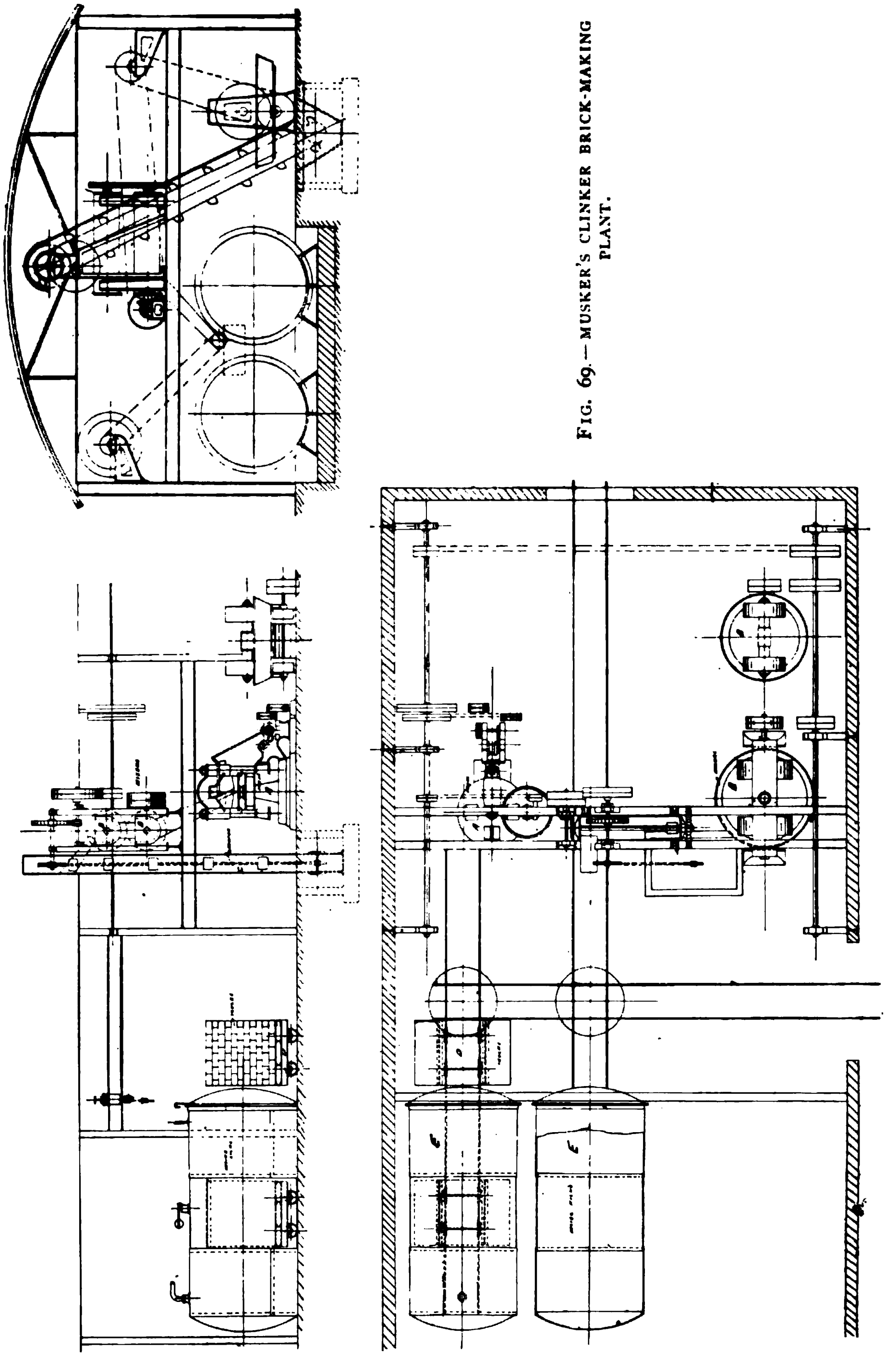


FIG. 69.—MUSKER'S CLINKER BRICK-MAKING PLANT.

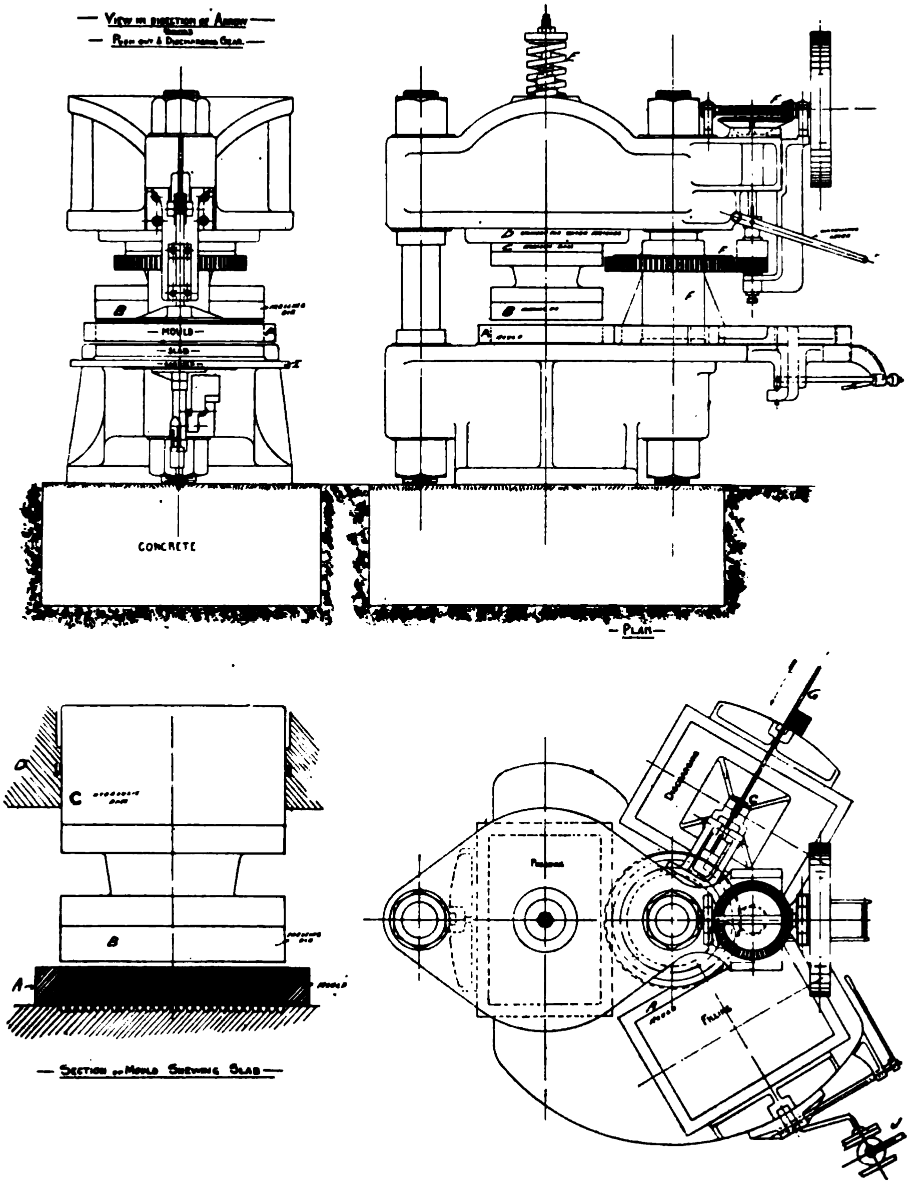

— View in direction of Arrow —
— Push out & Discharging Gear —
B
— MOULD —
— SLAB —
A
CONCRETE
D
C
B
A
F
— Plan —
C
B
A
— Section of Mould Shewing Slab —
Discharging
C
G
Pressing
A
Mould
Filling

FIG. 70.—MUSKER'S CLINKER SLAB-MAKING MACHINERY.

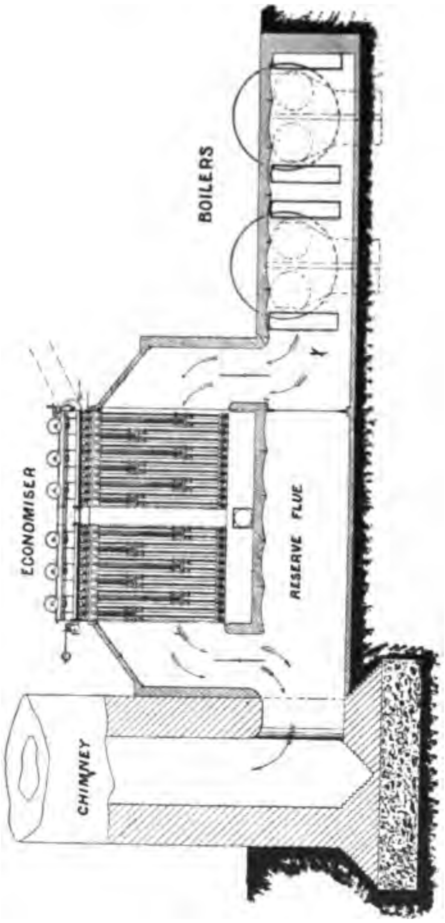


FIG. 71.—GREEN'S ECONOMISER.

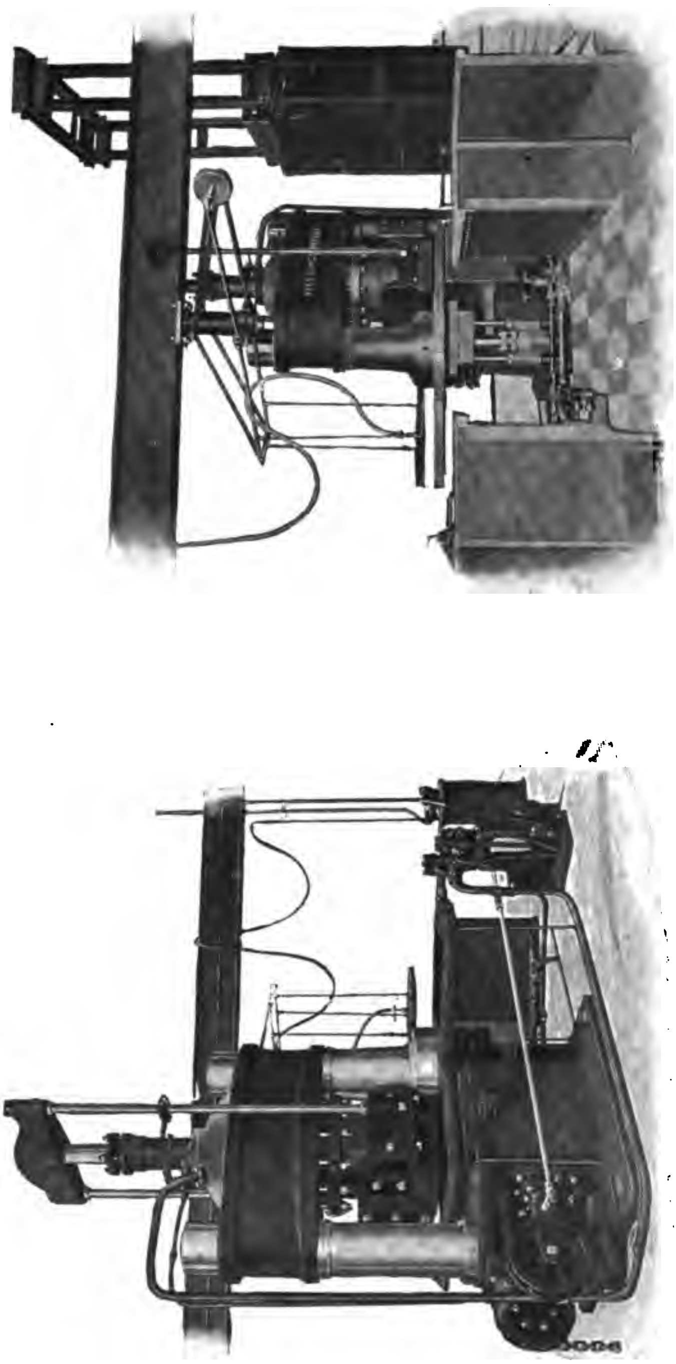


FIG. 72.—FIELDING AND PLATT'S SLAB MACHINERY AT THE HOLLINWOOD DESTRUCTOR WORKS, OLDHAM.

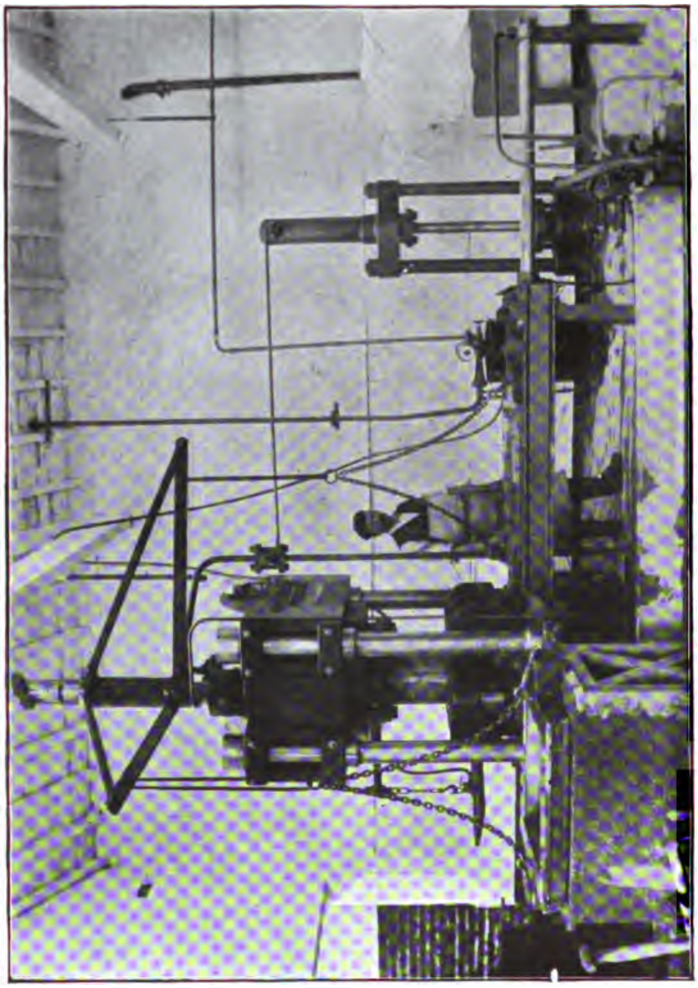


FIG. 73.—VIEW IN PRESS ROOM AT WITHINGTON DESTRUCTOR WORKS. SLAB MACHINERY BY FIELDING AND PLATT, LTD.

purposes, whereby the cost of burning is oftentimes more than recovered, and the residuum clinker is also utilized in the manufacture of paving slabs, bricks and mortar, and for other profitable purposes.

APPENDIX TO LECTURE II

CLASSIFIED LIST OF BRITISH MANUFACTURERS INTERESTED IN MAIN DRAINAGE, SEWAGE DISPOSAL, DESTRUCTORS, AND ALLIED BRANCHES

AIR COMPRESSORS.

Alley & Maclellan, Ltd.	Sentinel Works, Glasgow.
Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester
Belliss & Morcom, Ltd.	Ledsam Street, Birmingham.
Braithwaite, Isaac, & Son	Kendal.
Brotherhood, P.	Belvedere Road, S.E.
Campbell Gas Engine Co., Ltd.	Halifax.
Cole, Marchent & Morley, Ltd.	Prospect Foundry, Bradford.
Coles, H.	London Crane Works, Derby.
Consolidated Pneumatic Tool Co., Ltd.	9, Bridge Street, Westminster, S.W.
Craig, A. F., & Co., Ltd.	Paisley, N.B.
Davey, Paxman, & Co., Ltd.	Colchester.
Daw, A. & Z.	11, Queen Victoria Street, E.C.
De Bergue & Co., Ltd.	Manchester.
Easton & Co., Ltd.	Broad Sanctuary Chambers, S.W.
Ellison, W. T., & Co., Ltd.	Irlams-o'-th'-Height.
Fawcett, Preston & Co., Ltd.	Liverpool.
Fraser & Chalmers, Ltd.	43, Threadneedle Street, E.C.
Hathorn, Davey & Co.	Sun Foundry, Leeds.
Hughes & Lancaster	47, Victoria Street, S.W.
Jenkins, W. J., & Co., Ltd.	Retford.
Jessop & Appleby, Brothers, Ltd.	Leicester.
Larmuth, Thos., & Co.	Todleben Ironworks, Salford, Manchester.
Lacy-Hulbert & Co.	25, Victoria Street, S.W.
Leeds Engineering & Hydraulic Co.	Providence Works, Leeds.
Marryat & Place	28, Hatton Garden, E.C.
Meldrum Brothers, Ltd.	Atlantic Works, Manchester.
Newton, Bean, & Mitchell	Dudley Hill, Bradford.
Parsons, C. A., & Co.	Newcastle-on-Tyne.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.

Pulsometer Engineering Co., Ltd.	63, Queen Victoria Street, E.C.
Reader, E., & Sons	Phœnix Works, Nottingham.
Reavell & Co., Ltd.	Ipswich.
Richards, G., & Co., Ltd.	Broadheath, near Manchester.
Scott, G., & Son, Ltd.	44, Christian Street, E.
Siebe, Gorman & Co.	Westminster Bridge Road, S.E.
Tilghman's Patent Sand Blast Co., Ltd.	Broadheath, near Manchester.
Thwaites Brothers, Ltd.	Bradford.
Vauxhall Ironworks, Ltd.	Wandsworth Road, S.W.
Walker Brothers,	Pagefield Works, Wigan.
Westinghouse Brake Co., Ltd.	York Road, King's Cross, N.

BOILERS (STEAM).

Abbot, John, & Co., Ltd.	Gateshead-on-Tyne.
Abbott & Co. (Newark), Ltd.	Newark-on-Trent.
Adamson, Daniel, & Co.	Dukinfield, Manchester.
Alley & Maclellan, Ltd.	Sentinel Works, Glasgow.
Anderton & Sons	Accrington.
Bellamy, John, Ltd.	Millwall, E.
Belliss & Morcom, Ltd.	Ledsam Street, Birmingham.
Bodley Brothers & Co.	Exeter.
Burnet, L., & Co.	Govan, Glasgow.
Burrell, C., & Sons, Ltd.	Thetford.
Campbell & Calderwood	Soho Engine Works, Paisley.
Central Marine Engine Works	West Hartlepool.
Chaplin, Alex., & Co.	Govan, Glasgow.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Clayton, Son, & Co., Ltd.	Leeds City Boiler Works, Leeds.
Clayton & Shuttleworth, Ltd.	Lincoln.
Cochran & Co., Annan, Ltd.	Annan, N.B.
Coltanm, H., & Sons	Midland Ironworks, Loughborough.
Coltman, Walter W.	Central Boiler Works, Loughborough.
Cradley Boiler Co.	Cradley Heath, Staffs.
Craig, A. F., & Co., Ltd.	Paisley, N.B.
Dalglish, A. & W.	Pollokshaws, Glasgow.
Davey, Paxman, & Co., Ltd.	Colchester.
Day, Summers & Co., Ltd.	Southampton.
Dodman, Alfred, Ltd.	King's Lynn.
Easton & Bessemer, Ltd.	Taunton.
Easton & Co., Ltd.	Erith Iron Works, Erith, Kent.
Evans, D., Llewellin	120, Bute Street, Cardiff.
Farrer, A.	Newark-on-Trent.

Fawcett, Preston Co., Ltd.	Liverpool.
Fleming & Ferguson, Ltd.	Paisley, Scotland.
Foster, W., & Co., Ltd.	Lincoln.
Fowler, J., & Co. (Leeds), Ltd.	Leeds.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, E.C.
Galloways, Limited	Manchester.
Garrett, R., & Sons	Leiston Works, Suffolk.
Gimson & Co., Ltd.	Leicester.
Grantham Crank & Iron Co., Ltd.	Grantham.
Green, Thomas, & Son, Ltd.	Smithfield Ironworks, Leeds; and New Surrey Works, Southwark Street, S.E.
Hanna, Donald & Wilson	Paisley, N.B.
Hartley & Sugden, Ltd.	Halifax.
Hawthorn R. & W., Leslie & Co., Ltd.	Newcastle-on-Tyne.
Hayes, Edward	Stony Stratford, Wolverton.
Hindley, E. S., & Sons	11, Queen Victoria Street, E.C.
Hornsby, R., & Sons, Ltd.	Grantham.
Horsfield, Ralph, & Co.	Bredbury, near Stockport.
Isca Foundry and Engineering Co.	Newport, Mon.
Jessop & Appleby Brothers (Leicester & London), Ltd.	Leicester & London.
Kincaid, John G., & Co.	Greenock, Scotland.
Lees, T. & R.	Hollinwood, near Manchester.
Low Moor Iron Works	Bradford, Yorkshire.
Manlove, Alliott & Co., Ltd.	Nottingham.
Marshall, Sons & Co., Ltd.	Gainsborough.
McKie & Baxter	Govan, Glasgow.
Merryweather & Sons, Ltd.	63, Long Acre, W.C.
Mirrlees, Watson & Co., Ltd.	Scotland Street, Glasgow.
Mordey, Carney (Southampton), Ltd.	Woolston Works, Southampton.
Mumford, A. G.	Culver St. Ironworks, Colchester.
Napier Brothers, Ltd.	100, Hyde Park Street, Glasgow.
Norman, John	131A, St. Vincent Street, Glasgow.
Parsons Marine Steam Turbine Co. Ltd.	Turbinia Works, Wallsend-on-Tyne.
Penman & Co.	Strathclyde Street, Glasgow.
Piggott, Thos., & Co., Ltd.	Springhill, Birmingham.
Plenty & Son, Ltd.	Newbury, Berks.
Ransomes, Sims & Jefferies, Ltd.	Ipswich.
Richardsons, Westgarth & Co., Ltd.	West Hartlepool.

Robey & Co., Ltd.	Lincoln.
Rose, Downs & Thompson, Ltd.	Hull.
Ross & Duncan	Glasgow.
Rowland, B. R., & Co., Ltd.	Reddish, near Manchester.
Russell, Geo., & Co., Ltd.	Motherwell, near Glasgow.
Ruston, Proctor, & Co., Ltd.	Sheaf Ironworks, Lincoln.
Simpson, Strickland & Co., Ltd.	Dartmouth.
Sinclair, George	Albion Boiler Works, Leith, N.B.
Smedley Brothers, Ltd.	Belper.
Smith, A. & W., & Co., Ltd.	Eglinton Engine Works, Glasgow.
Smokeless Chimney Co., Ltd.	Albert Square, Manchester.
Spencer, W. H., & Co.	Hitchin, Herts,
Stirling Boiler Co., Ltd.	2, St. Andrew Square, Edinburgh.
Tangyes, Limited	Birmingham.
Tannett, Walker & Co., Ltd.	Hunslet, Leeds.
Thornycroft, J. I., & Co., Ltd.	Chiswick, W.
Tinker, Shenton & Co., Ltd.	Hyde, near Manchester.
Toward, T., & Co.	9, St. Lawrence, Newcastle-on-Tyne.
Turner, E. R., & F., Ltd.	Ipswich.
Vauxhall Iron Works Co., Ltd.	Wandsworth Road, S.W.
Vosper & Co., Ltd.	Portsmouth.
Williams & Robinson, Ltd.	Rugby.
Yarrow & Co., Ltd.	Poplar, E.

CLOSETS, CISTERNS, TANKS, ETC. (see also "Sanitary Ware," etc.) below).

Bawn, W. B., & Co.	49, West India Dock Road, London, E.
Burney & Co.	Westferry Road, Millwall, London, E.
Braby, F., & Co.	360, Euston Road, N.W.
Claughton Brothers, Ltd.	Bramley, Leeds.
Croggan & Co.	16, Upper Thames Street, E.C.
Dent & Hellyer	35, Red Lion Square, W.C.
London Galvanized Iron Co.	27, Wharf Road, City Road, N.
Moule's Patent Earth Closet Co.	5A, Garrick Street, W.C.
Place, J., & Sons, Ltd.	Darwen.
Sanitary Appliances Syndicate	13, King William Street, E.C.
Winn, C., & Co.	St. Thomas Works, Birmingham.

DISINFECTING APPARATUS.

Bradford, T., & Co.	Crescent Ironworks, Manchester.
Defries, J., & Sons, Ltd.	147, Houndsditch, London, E.C.
Formalin Hygienic Co.	9 and 10, St. Mary-at-Hill, E.C.

Goddard, Massey, & Warner	Nottingham.
Manlove, Alliott & Co., Ltd.	Nottingham.
Reeves Chemical Sanitation, Ltd.	17, Victoria Street, S.W.
Tullis, D. & J., Ltd.	Kilbowie Ironworks, near Glasgow.
United Alkali Co.	30, James Street, Liverpool.

DRAIN TESTERS, CLEANSING APPARATUS, RODS, ETC.

Ashford, W. & G.	12, Lower Essex Street, Birmingham.
Burn Brothers.	23 and 24, Charing Cross, S.W.
Cakebread, Robey & Co.	Stoke Newington, London, N.
Cooper, A. T.	92, Moray Road, Finsbury Park, N.
Hart, H.	29, Settles Street, Commercial Road, Stepney, London, E.
James, John	40, Sydney Street, Chelsea.
Kempe, Thomas	237 and 239, Coldharbour Lane, Brixton, S.W.
Merryweather & Sons	Greenwich Road, S.E.
Nicholls & Clarke, Ltd.	Shoreditch, E.
Pain, James	St. Mary Axe, E.C.
Winser & Co.	52, Buckingham Palace Road, S.W.

HYDRAULIC MACHINERY.

Abbot, John, & Co., Ltd.	Park Works, Gateshead-on-Tyne.
Armstrong, W. G.	Whitworth & Co.
Arrol, Sir William, & Co., Ltd.	Dalmarnock Ironworks, Bridgeton, Glasgow.
Bailey, W. H., & Co., Ltd.	Salford, Manchester.
Belliss & Morcom, Ltd.	Birmingham.
Berry, Henry, & Co., Ltd.	Croydon Works, Leeds.
Coles, H. J.	London Crane Works, Derby.
Cowans, Sheldon & Co., Ltd.	Carlisle.
Craig, A. F., & Co., Ltd.	Paisley, N.B.
Crow, Harvey & Co.	Park Grove Ironworks, Glasgow.
Davis & Primrose	Leith, N.B.
Drysdale & Co.	Bon Accord English Works, Glasgow.
De Bergue & Co., Ltd.	Manchester.
Dudbridge Iron Works	Stroud, Glos.
East Ferry Road Engineering Works Co., Ltd.	Millwall, E.

APPENDIX TO LECTURE II

Easton & Bessemer, Ltd.	Taunton.
Easton & Co., Ltd.	Erith, Kent.
Fawcett, Preston & Co.	Liverpool.
Fielding & Platt, Ltd. (Tweddell's System)	Gloucester.
Fullerton, Hodgart & Barclay, Ltd.	Vulcan Foundry and Engine Works, Paisley.
Galloways, Ltd.	Knott Mill, Manchester.
Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Greenwood & Batley, Ltd.	Armley Road, Leeds.
Gwynne & Co.	Brooke Street Works, Holborn, E.C.
Hathorn, Davey & Co., Ltd.	Leeds.
Hayward-Tyler, & Co.	90, Whitecross Street, E.C.
Hunter & English	Bow, E.
Leeds Engineering & Hydraulic Co., Ltd.	Providence Works, Cross Stamford Street, Leeds.
McOnie, A. & P. W.	Govan, Glasgow.
Marshall, Fleming & Jack	Motherwell, N.B.
Middleton, Robert	Sheepscar Foundry, Leeds.
Musgrave Brothers	Crown Point Foundry, Leeds.
Musker, C. & A., Ltd.	Liverpool.
Owens, S., & Co.	Whitefriars Street, E.C.
Pulsometer Engineering Co., Ltd.	Nine Elms Ironworks, Reading.
Rice & Co. (Leeds), Ltd.	Elland Road, Leeds.
Rose, Downs & Thompson, Ltd.	Old Foundry, Hull.
Simpson, J., & Co.	Pimlico, S.W.
Smith, A., & Stevens	Queen's Road, Battersea.
Smith Brothers & Co.	Kingston Engine Works, Glasgow.
Smith, Hugh, & Co.	Glasgow.
Stewart, D., & Co.	London Road Ironworks, Glasgow.
Tangyes Limited	Birmingham.
Tannett, Walker & Co.	Leeds.
Warner, R., & Co.	97, Queen Victoria Street, E.C.
Waygood & Otis, Ltd.	Falmouth Road, Great Dover Street, E.C.
West Hydraulic Engineering Co.	23, College Hill, E.C.
Wilson, J., & Son.	Vulcan Works, Johnstone, N.B.
Youngs	Ryland Street Works, Birmingham.

HYDRAULIC PRESSES.

Arrol, Sir William, & Co., Ltd.	Dalmarnock Ironworks, Bridgeton, Glasgow.

Bailey, W. H., & Co., Ltd.	Salford, Manchester.
Berry, Henry, & Co., Ltd.	Croydon Works, Leeds.
Bessemer, Hy., & Co., Ltd.	Sheffield.
Coles, H. J.	London Crane Works, Derby.
Drysdale & Co.	Bon Accord Engineering Works, Glasgow.
Fawcett, Preston & Co.	Liverpool.
Fielding & Platt, Ltd.	Gloucester.
Greenwood & Batley, Ltd.	Armley Road, Leeds.
Hadfield's Steel Foundry Co., Ltd.	Hecla Works, Sheffield.
Hayward-Tyler & Co.	90 and 92, Whitecross Street, E.C.
Jessop & Appleby Brothers (Leicester and London), Ltd.	Leicester and London.
Leeds Engineering and Hydraulic Co., Ltd.	Providence Works, Cross Stamford Street, Leeds.
McOnie A., & P. W.	Govan, Glasgow.
Middleton, Robert	Sheepscar Foundry, Leeds.
Musgrave Brothers	Crown Point Foundry, Leeds.
Musker, C. & A., Ltd.	Liverpool.
Piggott, Thos., & Co., Ltd.	Springhill, Birmingham.
Rice & Co. (Leeds), Ltd.	Elland Road, Leeds.
Rose, Downs & Thompson, Ltd.	Old Foundry, Hull.
Smith, Hugh, & Co.	Glasgow.
Stewart, D., & Co. (1902), Ltd.	London Road Ironworks, Glasgow.
Stothert & Pitt, Ltd.	Bath.
Tangyes, Limited	Cornwall Works, Birmingham.
Tannett, Walker, & Co., Ltd.	Leeds.
Taylor & Challen, Ltd.	Birmingham.
Waygood & Otis, Ltd.	Falmouth Road, S.E.

HYDRAULIC RAMS.

Armstrong, W. G.	Whitworth & Co.
Bailey, W. H., & Co., Ltd.	Salford, Manchester.
Blake, John, Ltd.	Accrington, Lancs.
Owens, S., & Co.	Whitefriars Street, E.C.

HEATING, LIGHTING, AND VENTILATING.

Ash, T., & Co.	Broad Street, Birmingham.
Boyle, R., & Son	64, Holborn Viaduct, London.
Buchan, W. P., & Co.	36, Renfrew Street, Glasgow.
Ewart & Son	346–350, Euston Road, N.W.
Keith, J., & Blackman Co., Ltd.	27, Farringdon Avenue, E.C.
King, J., Ltd.	Benson Street, Liverpool.

Kite, C., & Co.	Chalton Street, London, N.W.
Mason, W., F., Ltd.	Manchester.
Meadow Foundry Co.	Mansfield, Notts.
Messenger & Co.	Loughborough, Leicestershire.
Moffats, Ltd.	155, Farringdon Road, London.
Offa Ventilating Co.	64, Basinghall Street, E.C.
Royles, Ltd.	Irlam, near Manchester.
Shorland, E. H., & Brothers	Drake Street Works, Manchester.
Sturtevant Engineering Co.	147, Queen Victoria Street, E.C.
Sugg, William, & Co.	Vincent Works, Westminster, S.W.
Thames Bank Iron Co.	Upper Ground Street, London, S.E.

PUMPING ENGINES.

Abbot, John, & Co., Ltd.	Gateshead-on-Tyne.
Adamson, Daniel, & Co.	Dukinfield, Manchester.
Bailey, W. H., & Co., Ltd.	Salford, Manchester.
Belliss & Morcom, Ltd.	Birmingham.
Berry, Henry, & Co., Ltd.	Croydon Works, Leeds.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Davey, Henry	3, Princes Street, Westminster, S.W.
Davey, Paxman & Co., Ltd.	Colchester.
Easton & Co.	Erith, Kent.
Fielding & Platt, Ltd.	Gloucester.
Fleming & Ferguson, Ltd.	Paisley, N.B.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, E.C.
Fullerton, Hodgart, & Barclay, Ltd.	Vulcan Foundry and Engine Works, Paisley.
Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Gwynne, Ltd.	Brooke Street Works, E.C.
Hayward-Tyler & Co.	90, Whitecross Street, E.C.
Hathorn, Davey & Co., Ltd.	Leeds.
Jessop & Appleby Brothers (Leicester and London), Ltd.,	Leicester and London.
Leeds Engineering & Hydraulic Co., Ltd.	Providence Works, Cross Stamford Street, Leeds.
McOnie, A., & P. W.	Govan, Glasgow.
Moreland, R., & Son, Ltd.	25 and 27, Old Street, E.C.
Musgrave Brothers	Crown Point Foundry, Leeds.
Pulsometer Engineering Co., Ltd.	Nine Elms Ironworks, Reading.
Rice & Co. (Leeds), Ltd.	Elland Road, Leeds.
Robey & Co., Ltd.	Lincoln.
Sandycroft Foundry Co., Ltd.	Near Chester.
Simpson, J. & Co.	Engineers, Pimlico, S.W.

Smith, Hugh, & Co.	Glasgow.
Tangyes Limited	Birmingham.
Tannett, Walker, & Co., Ltd.	Leeds.
Warner, R., & Co.	97, Queen Victoria Street, E.C.

Pumps and Pumping Machinery.

Abbot, John, & Co., Ltd.	Gateshead-on-Tyne.
Allen, Wm.	70, Port Street, Manchester.
Allen, W. H., Son, & Co., Ltd.	Queen's Engineering Works, Bedford.
Bailey, W. H., & Co.	Salford, Manchester.
Baker Blower Engineering Co.	Stanley Works, Sheffield.
Baker's Patent Appliances Co., Ltd.	Melrose Street Works, Scarborough.
Batchelor, R. D.	73, Queen Victoria Street, E.C.
Berry, Henry, & Co., Ltd.	Croydon Works, Leeds.
Bever, Dorling & Co., Ltd.	Bowling Ironworks, Bradford.
Braithwaite, Isaac, & Son	Kendal.
British Thomson-Houston Co., Ltd.	Rugby.
Cameron, John, Ltd.	Oldfield Road Ironworks, Salford.
Carruthers, J. H., & Co., Ltd.	Polmadie Ironworks, Glasgow.
Chaplin, Alex., & Co.	Govan, Glasgow.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Clay Cross Co.	Clay Cross, near Chesterfield.
Clayton & Shuttleworth, Ltd.	Lincoln.
Cochrane, John	Barrhead, N.B.
Coles, H. J.	London Crane Works, Derby.
Crow, Harvey & Co.	Park Grove Ironworks, Glasgow.
Davey, Henry	3, Princes Street, Westminster, S.W.
Davey, Paxman & Co., Ltd.	Colchester.
Dempster, Moore & Co., Ltd.	49, Robertson Street, Glasgow.
Drum Engineering Co.	27, Charles Street, Bradford.
Drysdale & Co.	Bon Accord Engine Works, Glasgow.
East Ferry Road Engineering Works Co., Ltd.	Millwall, E.
Easton & Co., Ltd.	Erith, Kent.
Edwards Air Pump Syndicate, Ltd.	3 and 5, Crown Court, Old Broad Street, E.C.
Ellison, W. T., & Co., Ltd.	Irlams-o'-th'-Height, Manchester.
Erith's Engineering Co.	70, Gracechurch Street, E.C.
Evans, Joseph, & Sons	Wolverhampton.

APPENDIX TO LECTURE II

Fairburn, Lawson, Combe & Barbour, Ltd.	52, Limehouse Street, E.C.
Fawcett, Preston & Co., Ltd. . .	Liverpool.
Fielding & Platt, Ltd. . . .	Gloucester.
Fleming & Ferguson, Ltd. . .	Paisley, N.B.
Fraser & Chalmers, Ltd. . . .	3, London Wall Buildings, E.C.
Fullerton, Hodgart & Barclay, Ltd.	Vulcan Foundry and Engine Works, Paisley.
Galloways Ltd.	Knott Mill, Manchester.
Gillespie, John, & Co. . . .	1, Leadenhall Street, E.C.
Glenfield & Kennedy, Ltd. . .	Kilmarnock, N.B.
Greenwood & Batley, Ltd. . .	Armley Road, Leeds.
Gunther, W., & Sons	Central Works, Oldham.
Gwynne Ltd.	Brooke Street Works, E.C.
Gwynne, J. & H., Ltd. . . .	81, Cannon Street, E.C.
Hanna, Donald & Wilson . . .	Paisley.
Haste Patent Pump Co. . . .	Crown Buildings, Crown Court, Old Broad Street, E.C.
Hartnell, W., & Co., Ltd. . . .	Volt Works, Leeds.
Hathorn, Davey & Co., Ltd. . .	Leeds.
Hayward-Tyler & Co. . . .	90 and 92, Whitecross Street, E.C.
Holden & Brooke, Ltd. . . .	Sirius Works, West Gorton, Manchester.
Hornsby, R., & Sons, Ltd. . .	Grantham.
Hughes & Lancaster	47, Victoria Street, S.W.
Hunter & English	Bow, E.
Isca Foundry & Engineering Co. .	Newport, Mon.
Isler, C., & Co.	Artesian Works, Bear Lane, S.E.
Jessop & Appleby Brothers (Leicester and London), Ltd.	Leicester and London.
Kirkaldy, J., Ltd.	101, Leadenhall Street, E.C.
Körting Brothers	53, Victoria Street, S.W.
Lacy-Hulbert, & Co.	25, Victoria Street, S.W.
Lancaster & Tonge, Ltd. . . .	Pendleton, near Manchester.
Le Grand & Sutcliff	125, Bunhill Row, E.C.
Leeds Engineering & Hydraulic Co., Ltd.	Providence Works, Cross Stamford Street, Leeds.
Lobnitz & Co., Ltd.	Renfrew, Scotland.
Lund, E.	Park Ironworks, Stockport.
Mather & Platt	Manchester.
Merryweather & Sons, Ltd. . .	63, Long Acre, W.C.
Moreland, Richard, & Son, Ltd. .	25 and 27, Old Street, E.C.
Mumford, A. G.	Culver Street Ironworks, Colchester.
Musgrave Brothers	Crown Point Foundry, Leeds.

Musker, C. & A., Ltd.	Liverpool.
Newton, Bean & Mitchell	Dudley Hill, Bradford.
Owens, S., & Co.	Whitefriars Street, E.C.
Parsons, C. A., & Co.	Newcastle-on-Tyne.
Pearn, Frank, & Co., Ltd.	Manchester.
Perry, T., & Sons	Bilston, Staffs.
Picking, Hopkins & Co.	Arnold Works, Bow, E.
Piggott, Thos., & Co., Ltd.	Springhill, Birmingham.
Pulsometer Engineering Co., Ltd.	Nine Elms Ironworks, Reading.
Ransomes & Rapier, Ltd.	Ipswich.
Reader, E., & Sons, Ltd.	Nottingham.
Rice & Co. (Leeds), Ltd.	Elland Road, Leeds.
Richardson, A. W.	Skew Bridge Works, Patricroft, near Manchester.
Robey & Co., Ltd.	Lincoln.
Ruston, Proctor & Co., Ltd.	Sheaf Ironworks, Lincoln.
Scott, Ernest, & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
Shore, T., & Sons	Albion Foundry, Hanley.
Simpson, J., & Co.	101, Grosvenor Rd., Pimlico, S.W.
Stothert & Pitt, Ltd.	Bath.
Tangyes Limited	Birmingham.
Thwaites Brothers, Ltd.	Bradford.
Vauxhall Ironworks Co., Ltd.	Wandsworth Road., S.W.
Warner, R., & Co.	97, Queen Victoria Street, E.C.
Weir, G. & J., Ltd.	Cathcart, Glasgow.
West Hydraulic Engineering Co.	23, College Hill, E.C.
Westinghouse Brake Co., Ltd.	York Road, King's Cross, N.
Willcox, W. H., & Co., Ltd.	23, Southwark Street, S.E.

REFUSE DESTRUCTORS AND ACCESSORY APPLIANCES.

Baker, J., & Sons, Ltd.	Willesden Junction, N.W.
Ball, Frederick	Southwold, Suffolk.
Berry, H., & Co.	Croydon Works, Leeds.
Fielding & Platt	Gloucester.
Goddard, Massey & Warner	Nottingham.
Horsfall Destructor Co.	Lord Street Works, Whitehall Road, Leeds.
Heenan & Froude	4, Chapel Walks, Manchester.
Hughes & Stirling	London, and Liverpool.
Lowcock, Arthur, Ltd.	Coleham Foundry, Shrewsbury.
Manlove, Alliott & Co.	Nottingham.
Mason, W. F., Ltd.	Engineers, Longsight, Manchester.
Meldrum Brothers	Timperley, near Manchester.
Musker, C. & A., Ltd.	Liverpool.

APPENDIX TO LECTURE II

Sanitary Ware, Fittings, Pipes, Appliances, etc. (see also "Closets," etc., above).

Albion Clay Co., Ltd.	Woodville, Burton-on-Trent.
Ames-Crosta Sanitary Engineering Co., Ltd.	City Chambers South Parade, Nottingham.
Archer Pipe Co.	19, Great George Street, S.W.
Banner Sanitation Co.	24, Craven Street, W.C.
Bolding, J., & Son, Ltd.	298, Euston Road, N.W.
Bowes, Scott & Western, Ltd.	Broadway Chambers, Westminster, S.W.
Broad & Co.	Wharves, Paddington, W.
Burn Brothers	23 and 24, Charing Cross, Whitehall, S.W.
Calvert, F. C., & Co.	Bradford, Manchester.
Cameron & Robertson, Ltd.	Southbank Ironworks, Kirkintilloch, near Glasgow.
Candy & Co.	Newton Abbott, South Devon.
Claughton Brothers, Ltd.	Bramley, Leeds.
Cliff, J., & Sons	Wortley, Leeds.
Couzens, G. & F.	14, Tudor Road, Cardiff.
Crapper & Co.	50, Marlborough Road, London, S.W.
Darwen Sanitary Pipes, Ltd.	Darwen.
Dent & Hellyer	35, Red Lion Square, W.C.
Donington Sanitary Pipe & Fire-brick Co.,	Moira, near Ashby-de-la-Zouch.
Doulton & Co.	Lambeth, S.E.
Duckett & Son, J., Ltd.	Burnley, Lancs.
Economic House Drainage Repairing Co., Ltd.	164, Gresham House, Old Broad Street, E.C.
Farmiloe, F. & W.	Island Lead Mills, Limehouse, E.
Farrer, W. E.	Star Works, Cambridge Street, Birmingham.
Freeman & Hines, Ltd.	Westminster Palace Hotel (corner), Victoria Street, S.W.
Fyfe, John R., & Co.	Shipley, near Leeds.
Hall & Rogers	Upper Stanley Street, Dale Street, Manchester.
Hardy & Padmore	Worcester, England.
Hartshill Brick & Tile Co.	Stoke-on-Trent.
Hexter, Humpherson & Co.	Newton Abbott, Devon.
Hope & Son	Oak Lane Works, Limehouse, E.
Hughes & Lancaster	47, Victoria Street, S.W.
Hygienic Referendum	Gisburn Rd., Hornsey, London, N.

Ingham, W., & Sons (Branch of the Leeds Fireclay Co.)	Wortley, near Leeds.
Jennings, G., Ltd.	Stangate, London, S.E.
Knowles, J., & Co.	38, King's Road, St. Pancras, N.W.
Leeds Fireclay Co., Ltd.	20, Park Row, Leeds.
Liernur's English Syndicate, Ltd.	110, Cannon Street, E.C.
"Loco" Draining Apparatus Co., Ltd.	25, Cross Street, Manchester.
Lynde, F. C.	25, Cross Street, Manchester.
Macfarlane, W., & Co.	Saracen Foundry, Glasgow.
Mason, W. E.	Horwich, Lancashire.
Miller Flushing Siphon Syndicate	101, Leadenhall Street, E.C.
Morrison, Ingram & Co., Ltd.	Manchester.
Nevile Engineering Co.	Piston Foundry, Worcester.
New Expanded Metal Co.	York Mansion, York Street, Westminster, S.W.
Newton, Chambers & Co.	Thorncliffe, near Sheffield.
Nicholls & Clarke	Shoreditch, E.C.
North British Plumbing Co., Ltd.	86, Newman Street, W.
Oates & Green	Halifax.
Outram & Co.	Woodville, near Burton-on-Trent.
Palatine Engineering Co., Ltd.	10, Blackstock Street, Liverpool.
Parker & Hassall	Brougham Chambers, Nottingham.
Parker, V.	20, Victoria Street, Westminster, S.W.
Place, J., & Sons, Ltd.	Darwen.
Rapid Tap Filter Co.	134, Charing Cross Road, W.C.
Sanitary Engineering & Ventilating Co.	Victoria Street, S.W.
Sanitary Lead Lining & Pipe Bending Co., Ltd.	Cremore Wharf, Lots Road, London, S.W.
Sankey, J. H., & Son, Ltd.	Canning Town, E.
Shanks & Co.	Tubal Works, Barrhead, near Glasgow.
Sharp & Co.	Swadlincote, Burton-on-Trent.
Sharp, Jones & Co.	Bourne Valley Pottery & Rock Concrete Tube Works, Parkstone, Dorset.
Stanley Brothers	Nuneaton.
Staunton Colliery Sanitary Pipe Co.	Worthington, Ashby-de-la-Zouch.
Stiff & Sons	London Pottery, High Street, Lambeth, S.E.
Stone, J., & Co.	Deptford, London, S.E.

APPENDIX TO LECTURE II

Sutton & Co.	Union Pottery, Overseal, near Ashby-de-la-Zouch.
Turner-Croker Sanitary Appliance Co., Ltd.	21, Hatton Garden, Liverpool.
Twyfords, Ltd.	Hanley.
Tylor & Son	2, Newgate Street, London, E.C.
Waller, G., & Son	165, Queen Victoria Street, E.C.
Water Carriage Engineering Co., Ltd.	26–28, Mowbray, Street, Sheffield.
Watts, J., & Co.	Broadweir Works, Bristol.
Webb's Engineering Co., Ltd.	52, Queen Victoria Street, E.C.
Webb Lamp Co., Ltd.	11, Poultry, London, E.
Winn, C., & Co.	St. Thomas Works, Birmingham.
Winser & Co.	52, Buckingham Palace Road, S.W.
Wintle, F. E.	Woolston, near Southampton.
Wolstenholme, J., & Son	Radcliffe Bridge, Lancs.
Woodward, J., Ltd.	Swadlincote.
Wragg, T., & Sons, Ltd.	Swadlincote.
Wright, Sutcliffe & Sons	Globe Sanitary Works, Halifax.
Wyndham & Phillips	Ruabon, N. Wales.
Young & Marten, Ltd.	Caledonian Works, Stratford.

SEWERAGE IRONWORK.

Adams-Hydraulics, Ltd.	Engineers, York.
Beck & Co., Ltd.	130, Great Suffolk Street, Southwark, S.E.
Bird, F., & Co.	11, Great Castle Street, Regent Street, London, W.
Blakeborough, J., & Son	Brighouse, Yorks.
Ham, Baker & Co	13, Grosvenor Road, S.W.
Stone & Co.	Deptford.
Waller, George, & Co.	165, Queen Victoria Street, E.C.

SEWAGE TREATMENT AND ACCESSORY APPLIANCES.

Adams Patent Sewage Lift Co.	Engineers, York.
Candy, F., Pullen	The Cutting, Redhill, Surrey.
Cloke Brothers	3, St. Augustine's Road, N.W.
Farrer, W. E.	36, Cannon Street, Birmingham.
Freakley, J., & Co., Ltd.	Dudley Port, Tipton.
Goodridge, A. S.	7, Henrietta Street, Bath.
Graham, Joseph,	Engineer, Bank Chambers, Bank Street, Carlisle.
Harrison Engine Co., Ltd.	Cross Lane, Manchester.

International Purification Syndicate.	109, Victoria Street, S.W.
Johnson, S. H., & Co. . . .	Engineering Works, Stratford, E.
Mather & Platt	Salford Ironworks, Manchester.
Natural Purification Co. . . .	Sanitary Appliance Depot, Newark.
Oxygen Sewage, Ltd.	15, Waterhouse Street, Halifax.
Patent Automatic Sewage Distributors, Ltd.	4, Westminster Palace Gardens, London, S.W.
Septic Tank Co., Ltd. . . .	1, Victoria Street, Westminster, S.W.
Spence, P., & Sons, Ltd. . . .	Manchester.
Spongy Iron Co.	New Oxford Street, W.
Stoddart, F. W.	Bristol.
The Armo-crete Co.	5, Westminster Palace Gardens, S.W.
Universal Sewage Purification Co.	Littleover, Derby.
Wolstenholme, J., & Son . .	Radcliffe Bridge, Lancs.

LECTURE III

WATER SUPPLY—CONCLUSION

Water Supply

I COME now to a department of municipal engineering work which more immediately affects the public health of a community than that of any branch of public service falling within the scope of the duties of a Municipal Authority, viz., that of *Water Supply.*

The modern advances made in sanitary, chemical, and bacteriological knowledge especially, have, year by year, demonstrated more and more clearly the absolute necessity for an ample supply of water that shall be free from impurity at its source, and therefrom be zealously protected against all possibilities of pollution till safely delivered to the house of the consumer.

This task, in fact, embraces the whole business and responsibilities of the waterworks engineer. His duty begins with the selection at its source of a pure and otherwise suitable supply, and includes the measurement and collection of the waters so selected, as well as their storage, purification (if necessary), conveyance and ultimate distribution to the consumer. The system of works upon which communities are supplied with water are usually classified either as "gravitation works" or "pumping works," or, as is very frequently the case, they may be a combination of both types. In the gravitation works, the source of supply, usually a catchment area, is generally a considerable distance from the population supplied, and must be situated at a sufficient elevation to enable the water to be delivered by gravitation into service reservoirs within or near the water area or town boundaries. These service reservoirs must also, of course, in their turn, be situated at such an elevation as will readily command the tops of the highest buildings to be supplied after making ample allowance for the frictional losses occurring in the distributing system. In any large water-area, however, it not infrequently happens that a small portion of the district lies above the top water-line of the aforesaid service reservoirs, and in such a case the supply required by this area is pumped through the additional elevation and usually also over a "stand-pipe" fixed on the highest ground available, so as to give a sufficient pressure to supply the upper floors of the highest buildings. Great Britain possesses many excellent examples of gravitation supplies, notably those of Glasgow from Lochs Katrine and Arklet; Manchester from Lake Thirlmere; Liverpool from Lake Vyrnwy in North Wales, and Birmingham from Elan Valley in Mid-Wales.

The works involved in undertakings of this class mainly consist of the formation, by means of earthen or masonry dams, of large impounding and compensation reservoirs in the lowest suitable valley of the catchment area, including the diversion of waters from neighbouring subsidiary areas into the main reservoir usually by means of tunnelled aqueducts communicating between the different watersheds. Also, the construction of a main aqueduct, or aqueducts, from the impounding or storage reservoirs to the service reservoirs near the town to be supplied, and the numerous accessory works incidental thereto.

In a pumping scheme there is less of what may be called heavy engineering work in so far as the collection and conveyance of the water is concerned, but a large outlay must usually be incurred in the provision of boilers, engines, pumping machinery, and buildings, whilst the questions of filtration and distribution remain very much the same in either case. In a pumping works, the source of supply is at a lower level than the water area or distribution district, and all the water is therefore pumped through "rising mains" to high service reservoirs, from which the town is supplied. The sources of supply in such a case are generally from rivers, springs collected to one central reservoir, or underground water obtained by means of sunk wells, borings, or infiltration galleries. Pumping schemes are more general in the south and east of England, and gravitation supplies more common in the north and west, where many excellent gathering grounds of a barren and mountainous character, situated at suitable altitudes, are available, and where the average annual rainfall greatly exceeds that of the south-eastern counties.

The question of preference between gravitation and pumping schemes is one which depends entirely upon local circumstances. No general statement of value can be made, nor can a decision be given in any particular case until the possibilities of both have been considered in detail in conjunction with local conditions. In cases where an ample supply of equal purity, and in all other respects as well suited to the requirements of the population to be served, is available on either system, the question of cost will be the deciding factor. Speaking generally, the initial cost of a gravitation scheme is greatest, but, on the other hand, against this is to be balanced the *permanent* annual expenditure of a pumping works.

The water supply to the Metropolis (as will be referred to again later), is the largest example in the world of a system of pumping works, and has, until recently, been carried on by eight distinct companies at a great many different stations distributed throughout " Water-London " —the water being drawn from the rivers Thames and Lea and the underlying chalk formation. Substantial provision has also been made for the storage and subsidence of flood waters, and works of sand filtration have been carried to a high state of perfection.

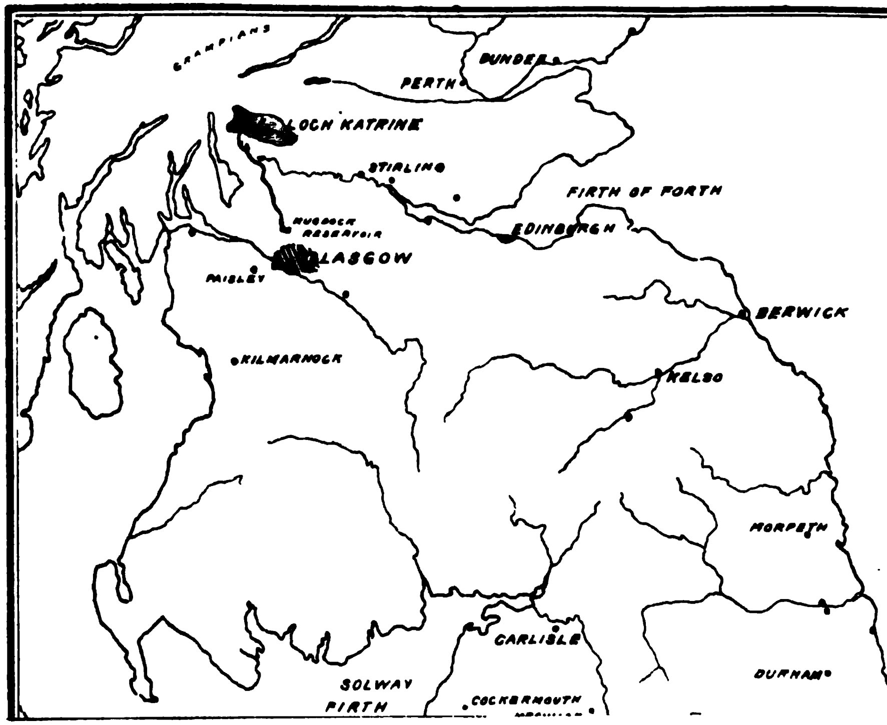
Brighton affords another good example of a pumping works, but in this case the whole supply is derived from underground sources by means of a number of wells and adits excavated in the chalk. In this town, it may also be mentioned that, owing to the widely varying surface levels of the district, a feature of the distribution system is the five " zones " or belts into which the water-area has been divided for the purpose of equalizing the pressure in the distributing mains.

The recent years of drought (1901–2) in Great Britain caused greater attention to be directed to the subject of water-supply from underground sources, and the increased conservation of these supplies, together with the greater stringency of the authorities charged with the administration of the Rivers Pollution Acts, indicates how fully the importance of this question is now appreciated. The quality of water obtainable from an underground source in any locality depends upon the chemical character of the strata through which it has percolated, and its quantity will depend on the hydro-geological structure of the district. Some of the principal water-bearing strata, named in geological order, commencing with the most recent, from which supplies have been obtained are: Valley gravels and drift deposits, Bagshot beds, Reading beds, Thanet sands, Chalk, Green-sand, Ashdown sand, Oolite, New Red Sandstone, and Millstone Grit.

The quantity of water which may be abstracted by means of wells or borings from any contributing underground area will depend upon a variety of circumstances, determinable to varying degrees of exactness, amongst which the following may be enumerated: (1) The boundaries or extent of the underground contributing area or watershed; (2) the area of "outcrop" of the water-bearing strata, and the extent to which the slope of adjoining impervious areas may conduct the rainfall falling thereon on to the porous "outcrop"; (3) the annual rainfall over the contributing area, and the proportion thereof percolating annually in at the outcrop, and ultimately finding its way to the underground store; (4) the degree of porosity or permeability of the water-bearing strata; (5) the quantity of water, or leakage, flowing out of the underground store, through natural outlets, as, for example, into the sea, or beds of rivers; and (6) the percentage of the total percolation into a water-bearing strata which is again recoverable by means of pumping stations. To define with a reasonable degree of certainty the true contributing area is by no means an easy matter, and must always involve a close geological and physical examination of the country in the neighbourhood of the outcrop.

Another important question is that of the gradual permanent depletion of underground supplies, as distinguished from mere local and seasonal changes of water levels depending on the fluctuations of the rainfall. A good deal has been heard for many years past of the depletion of the store of water in the chalk in the London basin and in the surrounding country districts, through the extensive pumping operations of the London water companies and the numerous private supplies also now drawn therefrom. The effects of these operations, it is alleged, are shown, during years of drought by the reduction of the water levels in wells and borings, by the reduction in the yield of springs and the drying up of river-heads, watercress beds, etc., and a marked decline during such periods in the volume of rivers in the country around London.

The burden of providing and maintaining a supply of one of the first necessaries of life is one which has, at one time or another, naturally exercised the serious attention of almost every authority, whether large or small, throughout this country. Of recent years the steady growth of p[illegible]n, the pollution of rivers and water-courses, the [illegible]med apparent depletion of some underground [illegible], and other causes, have tended to accentuate the [illegible]r vigorous action in the provision of a sufficient



MAP SHOWING GRAVITATION WATER SUPPLIES OF LARGE CITIES.

TABLE

City.	Extent of catchment area in acres.	Total volume of water impounded from catchment area in millions of galls.	Supply afforded per day in million galls.	No. of acres of catchment area per million galls. of daily supply.	Length of aqueduct in miles.
Glasgow . .	50,981	20,895	120	425	23·5
Manchester .	11,000	8,131	50	220	96
Bradford (New Nidd Valley Scheme)	18,200 (exclusive of compensation area)	2,596	20	910	32
Liverpool . .	23,500	13,000	40	588	68·5
Birmingham .	45,560	18,000	75	608	74
London (proposed Welsh Scheme)	312,400	104,600	415	753	Two 150 each.
Derwent Valley Scheme	31,946	10,013	33·3 (plus 16·7 million galls. for "compensation").	960	about 72 miles from Bamford.

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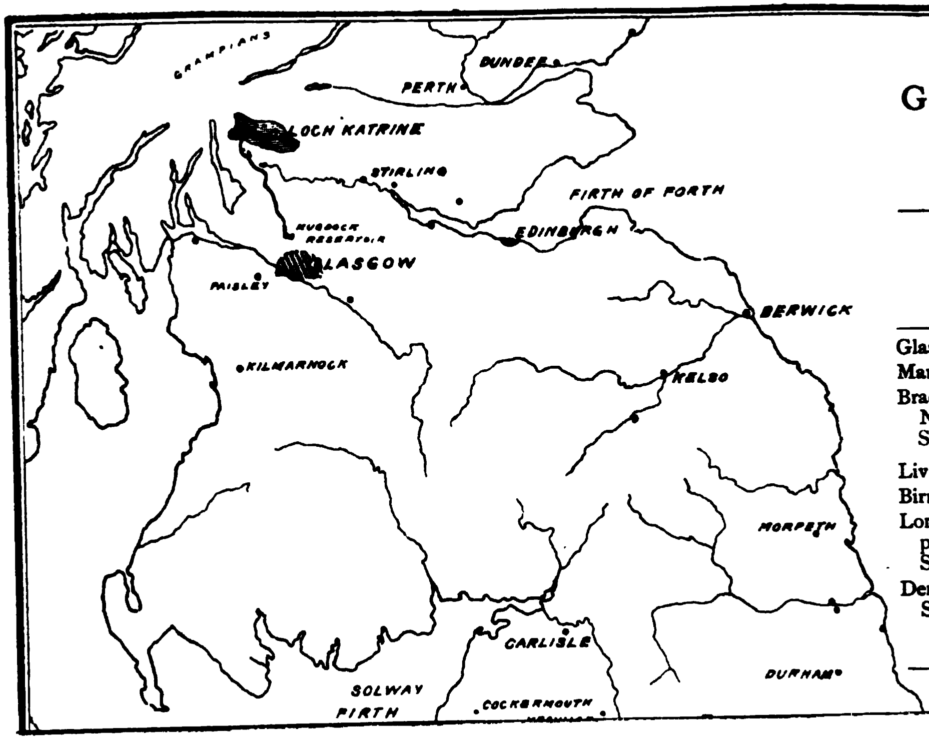
The burden of providing and maintaining a supply of one of the first necessaries of life is one which has, at one time or another, naturally exercised the serious attention of almost every authority, whether large or small, throughout this country. Of recent years the steady growth of population, the pollution of rivers and water-courses, the above named apparent depletion of some underground supplies, and other causes, have tended to accentuate the need for vigorous action in the provision of a sufficient



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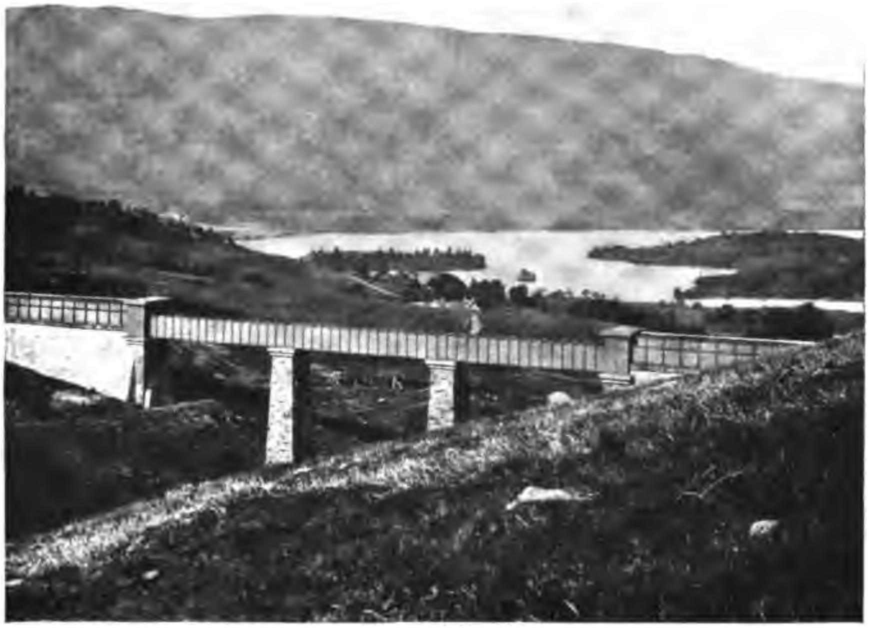
and reliable supply, and great activity in this direction has thus prevailed in city and village alike. Many large towns have gone boldly to work in making ample provision for the future needs of the increasing population within their boundaries, and amongst these are to be specially noted the important works carried out by such municipalities as Glasgow, Manchester, Liverpool, Birmingham, and Bradford (see Map, Fig. 21).

Glasgow has been particularly successful in the administration of its supply. Here the Corporation purchased the old water undertakings and spent large sums in securing a new source from Loch Katrine, with the result that the water rate has been reduced from 1*s*. 2*d*. in the £ to 6*d*., whilst the smaller properties are supplied without charge. The important step of obtaining statutory powers to construct these new works for bringing a plentiful supply of pure water into the city and its suburbs from Loch Katrine, in the Perthshire highlands, was taken by the Glasgow Council in 1855, and the new supply was inaugurated by her Majesty Queen Victoria in the year 1859. The necessary works consisted primarily of the raising of Loch Katrine 4 ft. above its previous summer level, the taking of 50 million gallons per day for the supply of the city, and the construction of a line of aqueduct and a service reservoir. Further powers were obtained in 1885, providing for (1) the raising of the lake another 5 ft.; (2) the taking of another 60 million gallons a day; (3) the construction of another line of aqueduct, and (4) the raising of Loch Arklet 25 ft., and the conveyance of its water into Loch Katrine by means of a tunnel. The first aqueduct is 8 ft. wide by 8 ft.

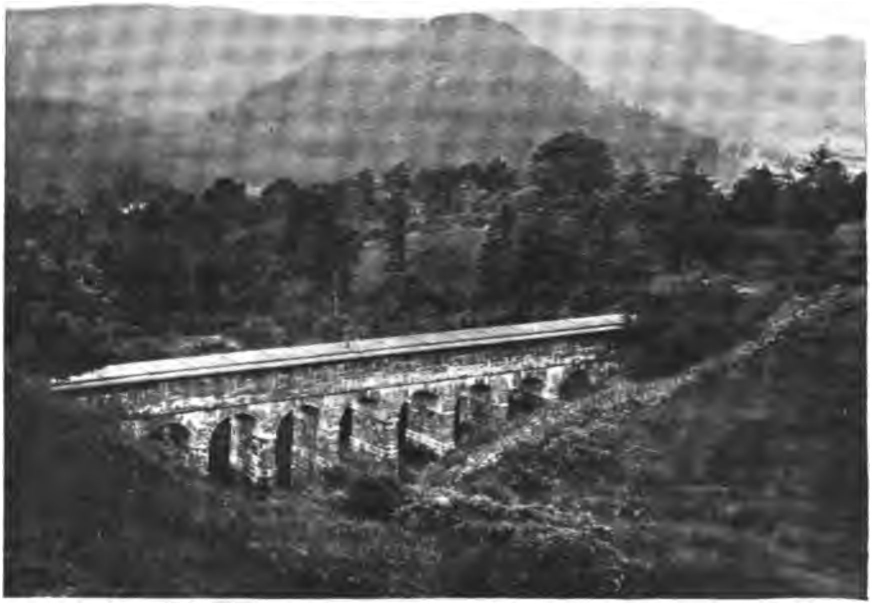
high, is about 26 miles in length, and capable of discharging 40 million gallons a day. The second is 12 ft. wide by 9 ft. high where passing through the rock unlined, and 10 ft. wide by 9 ft. high where lined with concrete. Its length is 23½ miles, and is capable of carrying 70 million gallons daily.

The total capital cost of the Glasgow waterworks has been about four million pounds, and the population now supplied is approximately 1,080,000 persons, with a daily consumption of over 60 million gallons, of which 35 gallons per head is for domestic uses and 21 gallons per head for trade purposes. The water is not filtered, being of great purity, and is of only about one degree of hardness. The gathering ground for the lake consists of some 36 square miles of rough hill country of metamorphosed mica-schist of the Lower Silurian system, and is situated at a considerable elevation above sea level.

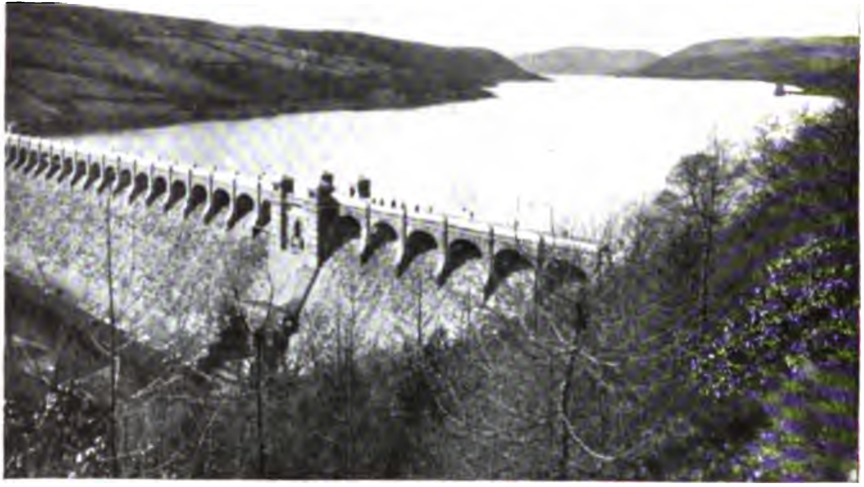
The water supply of the city of *Manchester* is obtained by gravitation from Longdendale, 18 miles to the east of the city, and from Lake Thirlmere in Cumberland. The Longdendale works were commenced in 1848, and those of Thirlmere in 1885. At Longdendale are a series of collecting and storage reservoirs of a total capacity of 4,187 million gallons, and the city possesses a service reservoir capacity of 1,798 million gallons, covering a surface of 340½ acres. The total cost of the Longdendale works, including those taken over by the Corporation from the old company, amounted to nearly 3¼ million pounds. In addition to the 25 million gallons a day available from Longdendale, the Corporation obtained powers in 1879 for the bolder scheme



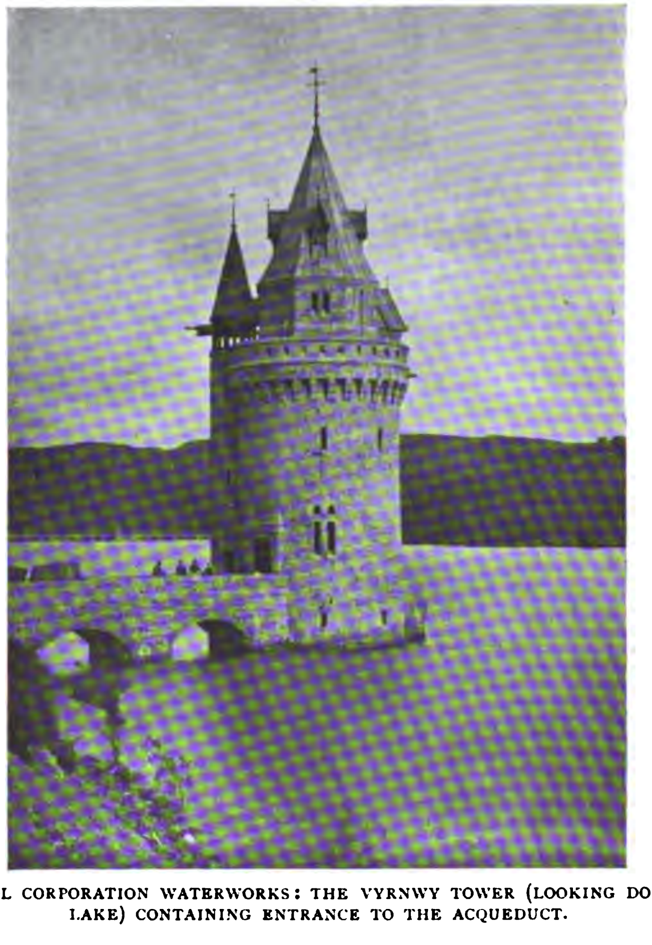
GLASGOW CORPORATION WATERWORKS: AQUEDUCT BRIDGE, NO. I., NEAR CULEGARTON, 6½ MILES FROM LOCH KATRINE, LOOKING TOWARDS LOCH ARD.



GLASGOW CORPORATION WATERWORKS; AQUEDUCT BRIDGE NEAR DUNTREATH CASTLE, 22 MILES FROM LOCH KATRINE.



LIVERPOOL CORPORATION WATERWORKS; VYRNWY RESERVOIR AND MASONRY DAM.



LIVERPOOL CORPORATION WATERWORKS: THE VYRNWY TOWER (LOOKING DOWN THE LAKE) CONTAINING ENTRANCE TO THE ACQUEDUCT.

of bringing a total of 50 million gallons daily from Lake Thirlmere through an aqueduct 96 miles in length and 7 ft. in diameter, terminating in a new service reservoir at Prestwich, about four miles from the city. The lake has a drainage area of 11,000 acres, over which a rainfall of from 60 to 137 inches is experienced. The natural level of the lake has been raised 50 ft. by means of a concrete masonry dam, and the additional capacity thus obtained is 8,131 million gallons, which is equal to 32·6 inches over the whole catchment area.

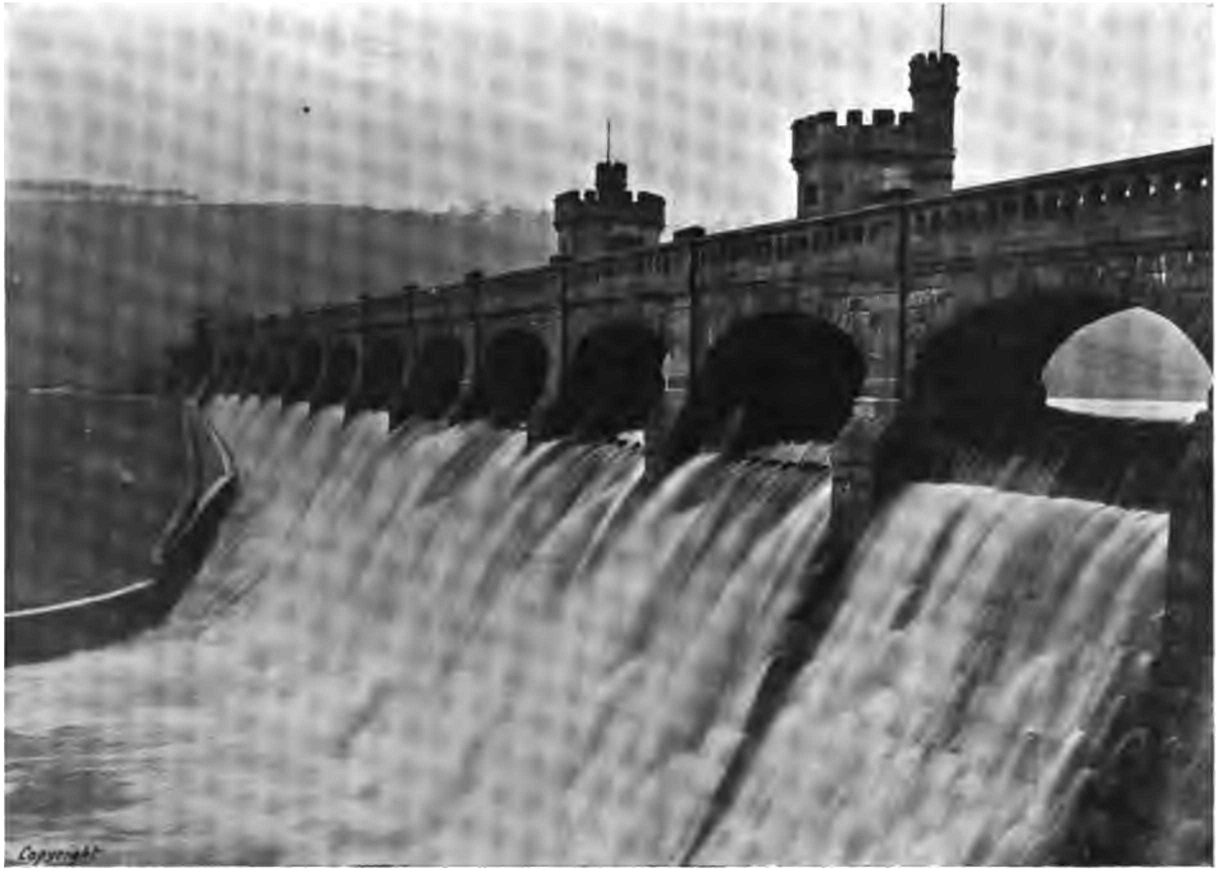
The cost of the Thirlemere undertaking to the date of opening in 1894 was about £2,800,000,and the whole scheme, with the four pipe lines proposed to be put down, is estimated to cost a sum of £4,500,000. The total population depending on the Corporation for water is about 1,100,000, distributed over a water area of some 90 square miles, and consuming 33 million gallons daily. The consumption per head is about 30 gallons, 17 gallons being for domestic purposes and 13 for trade.

Equal activity has been shown by the Corporation of *Liverpool* in providing for the increasing demands of its growing population. The supply in this case is from deep wells in the New Red Sandstone, from the Rivington watershed in Lancashire, and from Lake Vyrnwy in Montgomeryshire, North Wales. The Rivington reservoirs were commenced in 1852, and the Vyrnwy works begun in 1881 and completed in 1892. The water-shed at Rivington consists of 10,000 acres of sparsely inhabited hill and moorland on the millstone grit formation, and here seven reservoirs have been formed by earthen embankments impounding

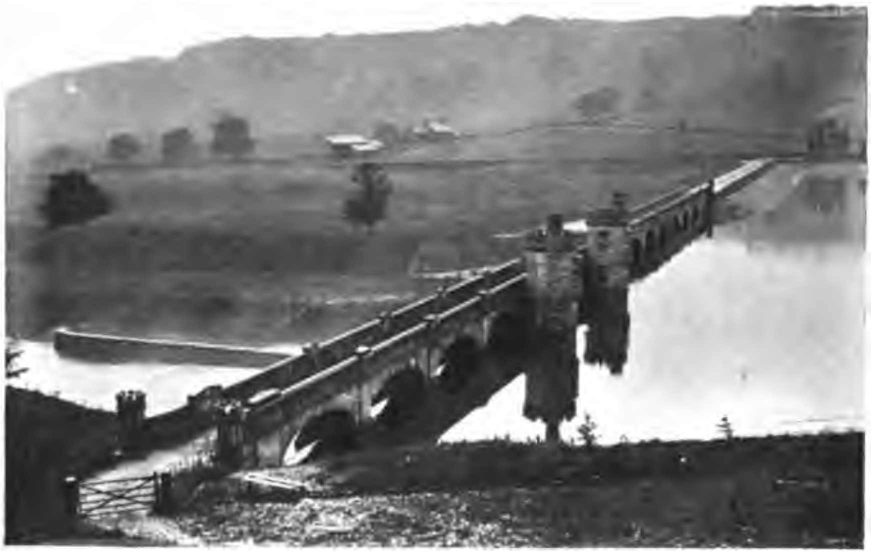
4,105 million gallons of water. An aqueduct, 24½ miles long, takes the supply to Liverpool, and from this source about 42 per cent. of the city's requirements were derived during the year 1901.

The area of the Vyrnwy gathering ground is 22,742 acres, situated on the Upper and Lower Silurian formations, and the lake has been formed by building a large masonry dam across the stream of that name. The volume thus impounded is sufficient to yield a supply of 40 million gallons a day to the city of Liverpool. The water is brought into the Prescott service reservoir at Liverpool by means of an aqueduct 68½ miles long. The construction of this aqueduct presented many engineering features of great difficulty in the crossing of railways, streams, etc., including the Manchester Ship Canal, and the River Mersey. The city of Liverpool has eight service reservoirs, of a total capacity of 31½ million gallons, and the average daily supply within the compulsory area was 26¼ million gallons in 1901. The population supplied is about 842,000, and the average consumption per head 31 gallons a day for trade and domestic purposes. The total water sent out by the Liverpool waterworks during the year 1901, including "compensation" to the rivers in Lancashire and Montgomeryshire, was no less than 76½ million tons, and the total cost of the waterworks undertakings has exceeded five million pounds.

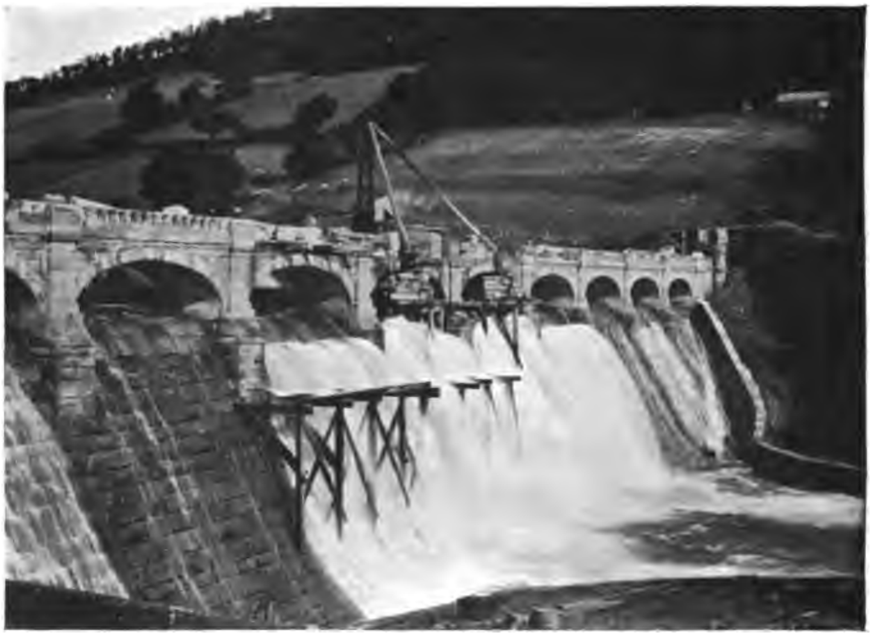
Important works have also been carried out for the supply of *Bradford* in the valleys of the rivers Wharfe, Aire, and Nidd, and these have been largely augmented by recent additions thereto in the upper Nidd Valley, where an additional reservoir storage capacity of 2,596 million



BRADFORD CORPORATION WATERWORKS: GOUTHWAITE RESERVOIR SHOWING OVERFLOW.
(*Photo by O. Nicholson, Water Dept., Bradford.*)



BRADFORD CORPORATION WATERWORKS ; GOUTHWAITE RESERVOIR MASONRY DAM.
(*Photo by O. Nicholson, Water Dept., Bradford.*)



BRADFORD CORPORATION WATERWORKS ; GOUTHWAITE RESERVOIR, MASONRY DAM,
DOWN STREAMFACE-FLOOD, OCT. 4, 1899.
(*Photo by O. Nicholson, Water Dept., Bradford.*)

gallons has been provided, exclusive of a new compensation reservoir of 1,564 million gallons. This new source has been connected to Bradford by means of an aqueduct 32 miles long, the internal dimensions of which are 5 ft. 6 in. by 6 ft. 3 in. high. The requirements of the city average about 13 million gallons a day for a population of 450,000 persons within a water area of 118 square miles. The original works cost about £2,300,000, and are capable of yielding some 11 million gallons per day, whilst the new Nidd Valley works will give a supply of over 20 million gallons daily, and are estimated to cost 1½ million pounds when finished.

A large Welsh gravitation scheme for the better supply of the city of *Birmingham* has been projected on the boldest lines to meet the future wants of the city, and the first instalment is now nearing completion. A catchment area of 45,562 acres around the valleys of the Elan and Claerwen has been appropriated by the Corporation, within which are to be built, in stages, a series of six storage reservoirs of an aggregate capacity of 17,360 million gallons. The full scheme will ultimately be capable of yielding a supply of 75 million gallons daily to the city, and to which the water is to be conveyed by an aqueduct 73 miles in length. This project is one of the most prominent instances of British progress in this department of municipal engineering, and will place the city of Birmingham in the enjoyment of an ample, reliable, and invaluable supply for a very long period to come. The total estimated cost for the entire scheme, including the purchase of the watershed, is £6,600,000.

The towns of Derby, Leicester, Nottingham, and Sheffield are jointly interested in an important gravitation scheme now being carried out in the *Derwent Valley*, consisting of large impounding reservoirs on the streams Derwent, Alport, and Ashop, which will be capable of yielding an ample supplementary supply to these important towns.

The case of the *London* water supply is somewhat unique, and although it has been the subject of serious consideration for very many years past, this vast population remains to-day dependent upon the rivers Thames and Lea, and the underground waters contained in the chalk, for its huge daily requirements. Parliament has appreciated the importance of the question, and Royal Commissions have at various intervals investigated the conditions which now obtain in the metropolis, and have formed forecasts of the probable conditions and requirements of forty to fifty years hence. The Duke of Richmond's Commission sat in 1869, Lord Balfour's Commission in 1893, and so recent as January, 1900, was issued the report of Lord Llandaff's Commission on the problem of the metropolitan supply. No material change in the methods or sources of supply have, however, yet been brought about, but questions relative to such a change continue to occupy a prominent place in the minds of the authorities responsible for the control of this important question. The present water supply of London involves the distribution of some 210 million gallons of water daily, to a population of 6 millions of people, a responsibility which, until the recent formation of the Metropolitan Water Board, has been in the hands of eight water companies. Of the various schemes which have been seriously brought forward for the better supply of the metropolis, the most recent and complete is that elaborated by Sir Alexander Binnie, M.I.C.E., which was laid before Lord Llandaff's Commission appointed in 1897. The sources of supply which were proposed to be utilized lie within the counties of Brecon, Cardigan, Radnor, and Montgomery at the head waters of the rivers Wye, Towy, and Usk, and at an elevation of from 600 ft. to 2,800 ft. above sea level. Here storage reservoirs were to be made, capable of impounding 104,600 million gallons of water for London and for " compensation " to the streams, and from which London was to receive, when the full scheme had been matured according to the necessities of the growth of population, a supply of 415 million gallons a day of the purest water from the Welsh mountain water-sheds. This was to be conveyed to London in two large aqueducts, each about 150 miles in length, and the total cost of the entire scheme was estimated at 39 million pounds.

One might prolong almost indefinitely this sketch of municipal activity in the department of water engineering in Great Britain. There is scarcely a town that has not during recent years carried out important works for the purpose of augmenting and improving its supply.

Most of such undertakings have embraced points requiring originality of design and improved and more expeditious methods of execution. All have called for the application of the highest class of Waterworks machinery, fittings, and apparatus of various kinds, and the British manufacturer has thus had a wide and busy field of operations in supplying the requirements of this department of engineering work.

To attempt anything approaching a complete account of the principal productions of our leading manufacturers in this connexion would be obviously quite impossible within the scope of the present lecture. A reference to a few of the principal typical examples and their uses will be all that can be here attempted. Such plant consists mainly of steam, gas, and oil engines; mains, valves, and hydrants of various descriptions; standpipes, outlet towers, break-pressure tanks, and automatic stop valves; water meters, taps, cisterns, and other house fittings used in the distribution of water. Also should be mentioned the various plant used in the boring of deep wells and in the raising of water therefrom.

Of the makers of general waterworks apparatus and plant, other than engine power and pumping machinery, a few only can be mentioned. Amongst these are the names of Messrs. J. Blakeborough & Sons; Ham, Baker & Co.; F. Bird & Co., Stone & Co., Glenfield and Kennedy, T. Piggott & Co., Guest and Chrimes, J. Tylor & Sons; Hayward-Tyler and Co., and George Kent.

Messrs. J. Blakeborough & Sons, of Brighouse, Yorkshire, are makers of all classes of appliances for the storage, control, filtration, and distribution of water for large and small towns alike, also of hydrants, fire extinguishing apparatus, and house fittings. Fig. 2 shows the top and bottom parts of one of that firm's cast-iron outlet towers, of about 8 ft. diameter, suitable for reservoirs up to 80 ft. deep.

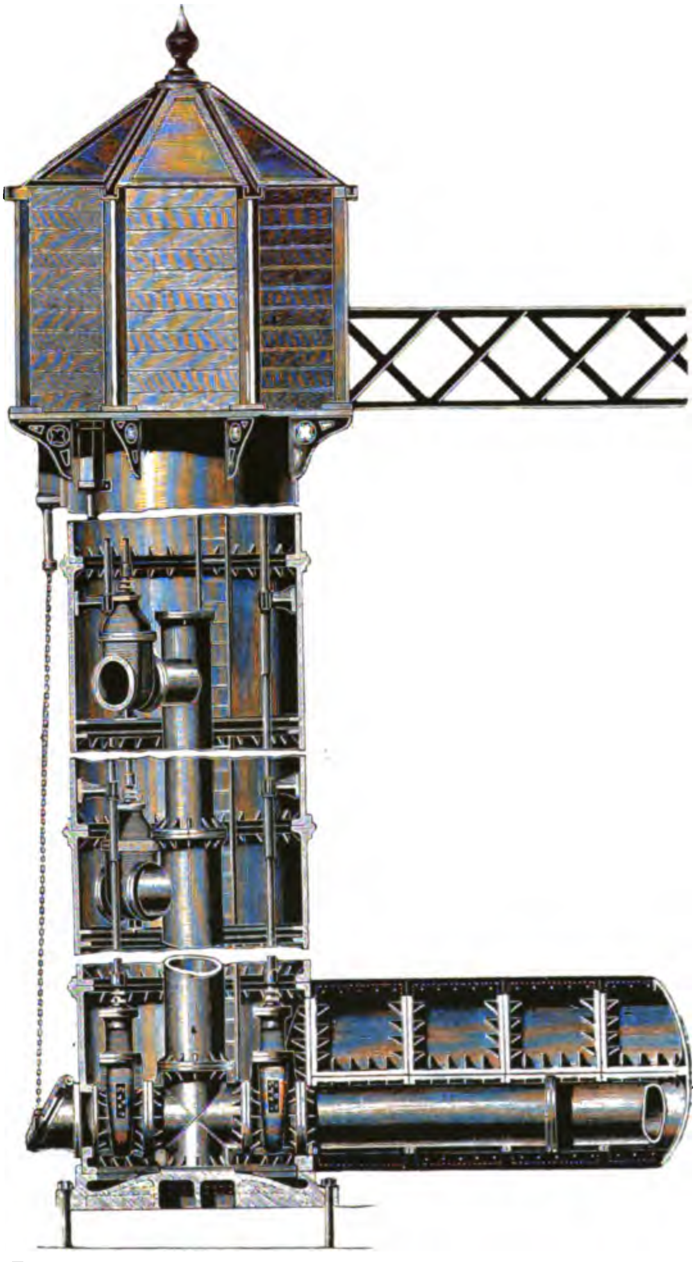


FIG. 2.—CAST-IRON OUTLET TOWER (BLAKEBOROUGH AND SONS).

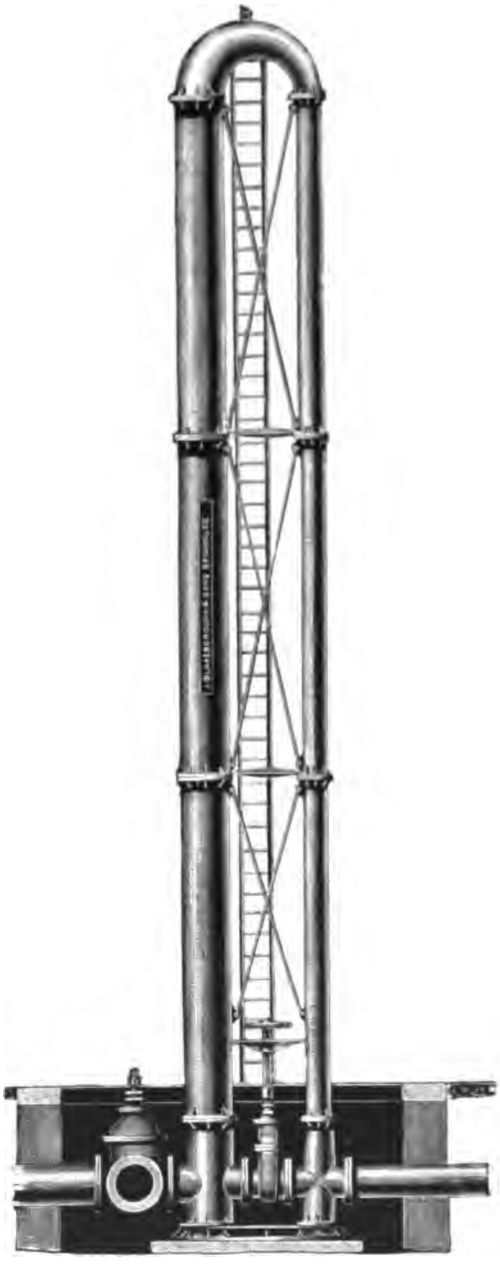


FIG. 3.—CAST-IRON STAND PIPE (BLAKEBOROUGH AND SONS).

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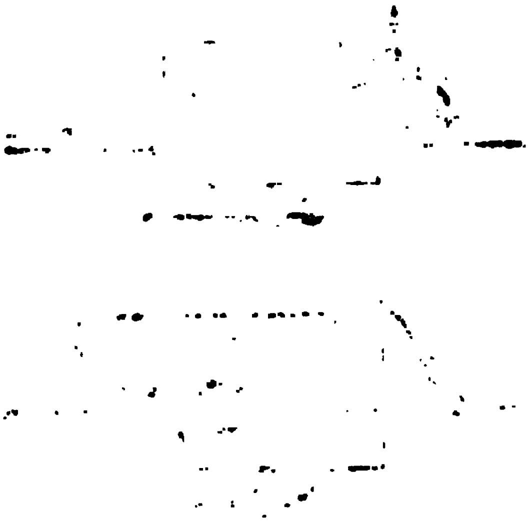


A cast-iron "standpipe," for use in connexion with pumping engines, for maintaining a constant head of pressure upon the pumps and in the mains is shown in Fig. 3.

In a line of water main it is frequently necessary to reduce or break the pressure by taking off all previous "head" up to a given point. This is accomplished by a reducing or break-pressure tank as illustrated in Fig. 4, which also shows a by-pass arrangement by which the whole available head can be used when so desired.

On the Thirlmere aqueduct of the Manchester waterworks large treble-door sluice valves of 40-inch bore were used, similar to that shown in Fig. 5; and on the Liverpool works large valves with by-pass, spur-wheel gearing and indicator similar to Fig. 6 were supplied by Messrs. J. Blakeborough & Sons.

Fig. 7 shows a cast-iron automatic stop-valve as used on large mains for the purpose of automatically shutting off the water in case of burst, and Fig. 8 is a double self-acting air and stop valve combined, a large number of which are in use on the Thirlmere aqueduct.

A reflux valve, as made by Messrs. Blakeborough & Sons, for large pumping or gravitation water mains in hilly districts, is shown in Fig. 9; and a pressure-reducing valve for equalizing pressure in hilly districts by reducing the pressure on the distributing mains in the lower parts of the area of supply is illustrated in Fig. 10.

An apparatus for drilling mains under pressure and making connexions without loss of water or shutting off the supply, is given in Fig. 12, and Fenney's pipe- and pipe-joint cutting machine, with trench gear, keys, handles, etc., for cutting out joints in pipes is illustrated by Fig. 13.

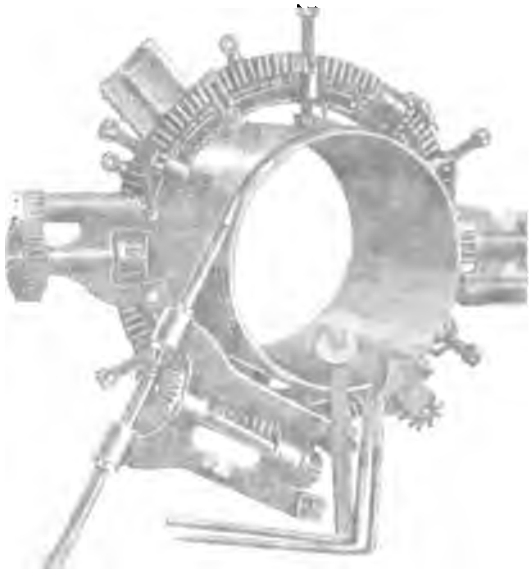
An apparatus for tapping mains *not* under pressure is shown in Fig. 14.

As examples of waterworks testing apparatus may be mentioned, Fig. 15, showing a large massive hydraulic pipe-testing machine to test up to 12 ft. 6 in. in length and 48 in. bore; Fig. 16, showing a testing machine for proving hydrants and valves of all kinds up to 6 in. bore; Fig. 17, illustrating an apparatus for testing taps, ferrules, etc., with pressure gauge, and Fig. 18, showing Beck & Co.'s apparatus for testing water meters.

The double fire hydrant as used by the London County Council is shown in Fig. 11, from which two hose pipes may be used from the same point.

A very important appliance in connexion with all waterworks undertakings is the "water meter," of which a great variety of improved types are now on the English market. Of the *positive* type meters may be mentioned Kent's "Absolute" (Fig. 19), the "Frost" or "Manchester" meter (Fig. 20), the "Imperial" (Schönheyder) (Fig. 21), Kennedy's (Fig. 22), Tylor's (Fig. 23), and Kent's "Standard" positive reciprocating piston meter (Fig. 24). Of the *inferential* class we have Siemens' (Fig. 25), Tylor's (Fig. 26), and others. Of the *volume or capacity* type are the "Bee" meter (Fig. 27), and Kent's "Uniform" meter (Fig. 28). Deacon's waste-detection meter is shown in Fig. 29, and is made by the Palatine Engineering Co., Ltd.

For measuring large volumes of water in trunk or other



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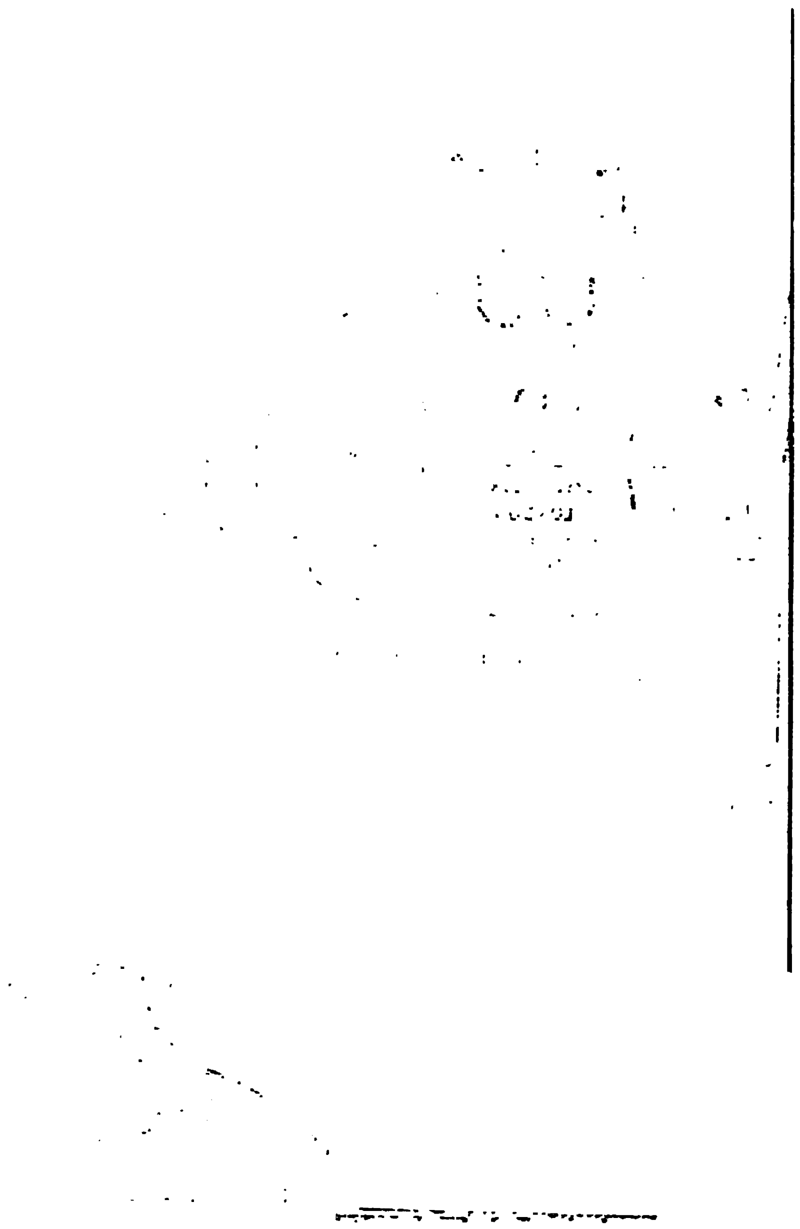

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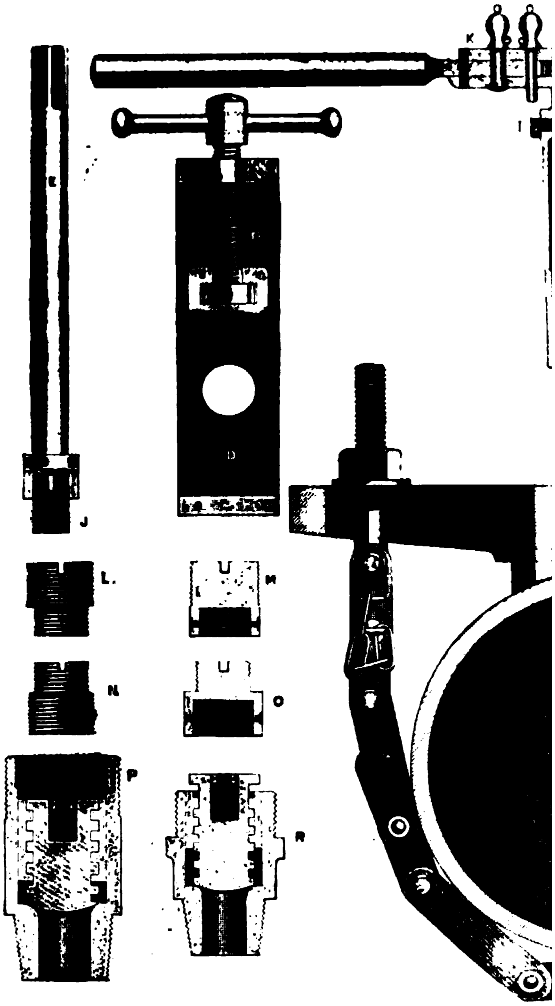
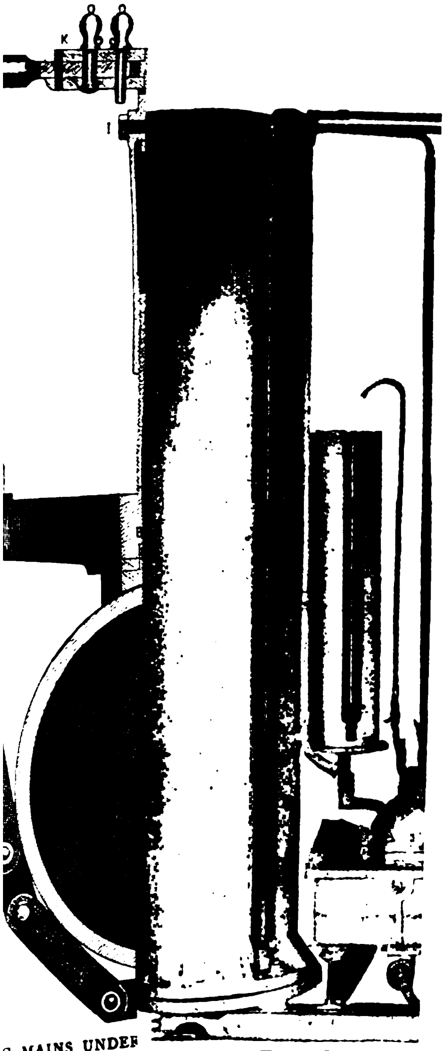


FIG. 12.—APPARATUS FOR DRILLING MAINS UNDE



G MAINS UNDER

FIG. 18.—TESTIN

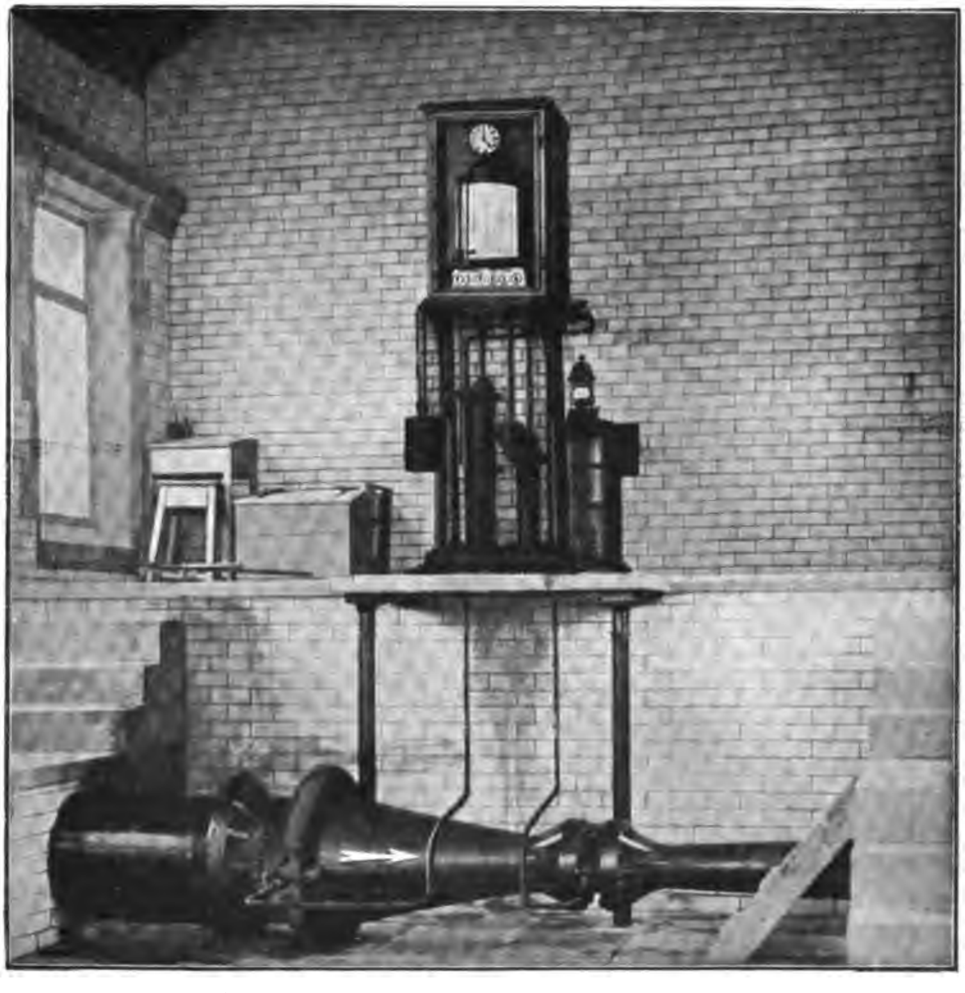


FIG. 30.—KENT'S "VENTURI" METER AT THE OLDHAM CORPORATION WATERWORKS.

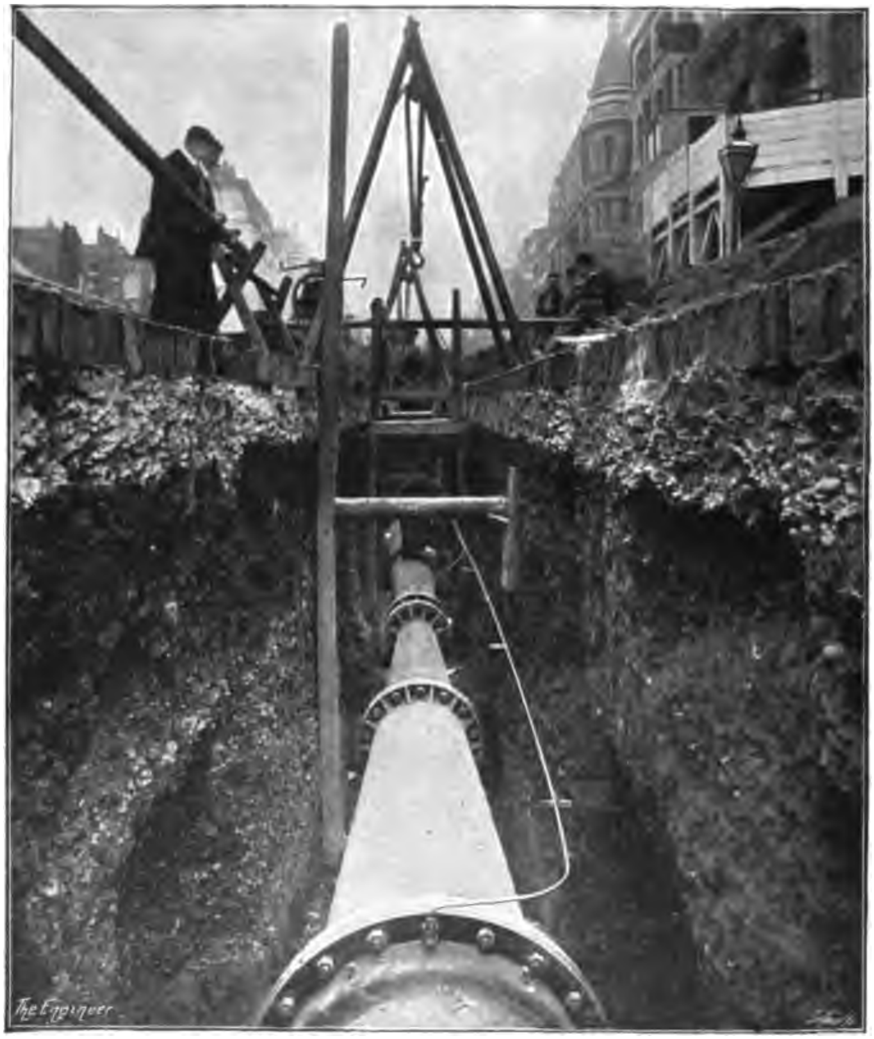


FIG. 31.—THE "VENTURI" METER ON A 30-INCH MAIN IN OXFORD STREET, LONDON.

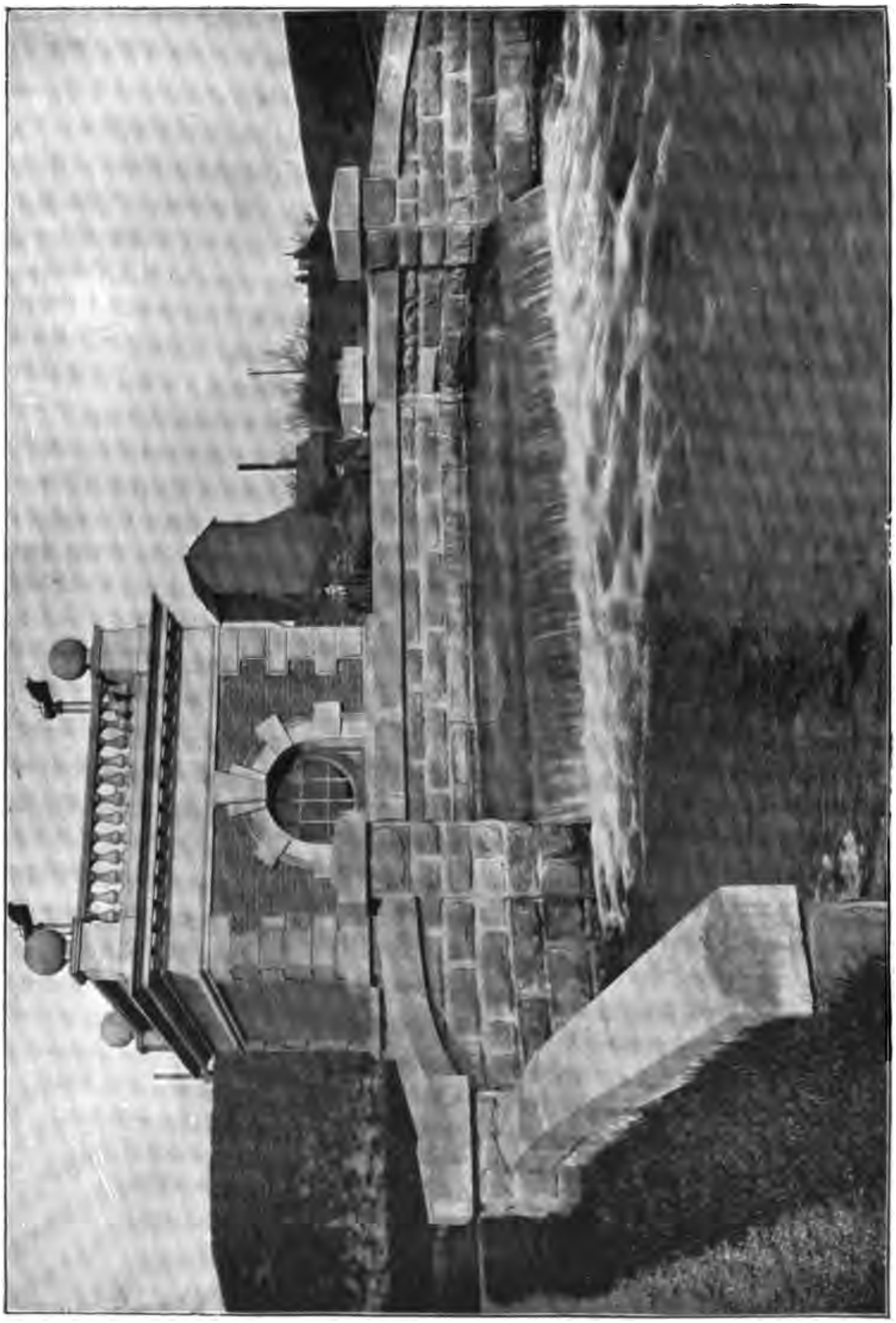


FIG. 32.—"VENTURI" METER HOUSE AT THE EAST LONDON WATERWORKS, LEYTON, N.E.
The flow actually being measured is at the rate of 37 million gallons (168,000 cubic metres) per day.

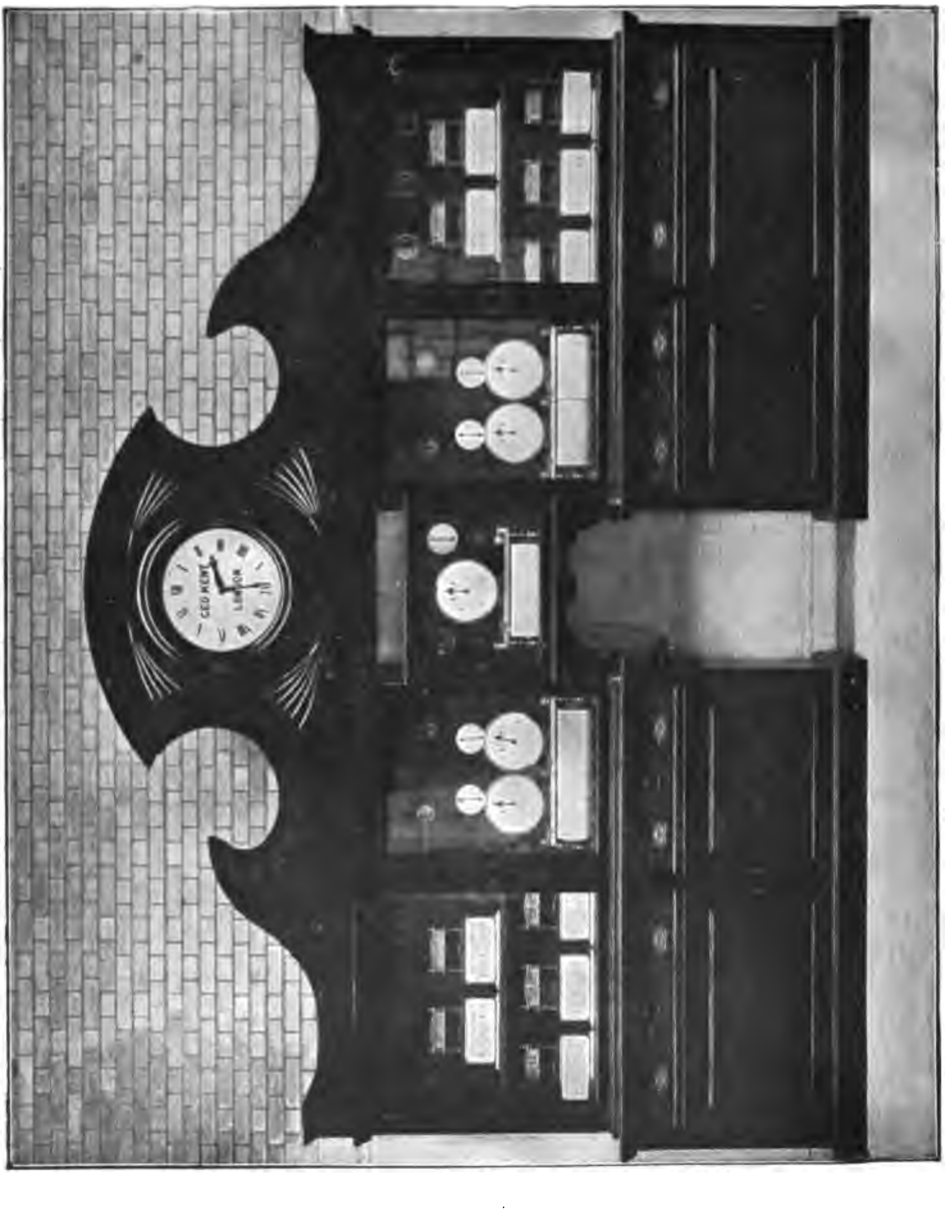


FIG. 33.—CABINET OF WATER MEASURING INSTRUMENTS, BY GEO. KENT, LONDON, AS FIXED AT THE STAINES RESERVOIRS (LONDON WATER SUPPLY).

mains Kent's "Venturi" meter (Herschel's patent) is a very useful appliance and is very largely used for this purpose. A view of this meter as fixed at the Oldham Corporation waterworks, England, is given in Fig. 30, whilst Fig. 31 shows this type of meter fixed on a 30-in. main in Oxford Street, London. This is one of a number that have been used in linking up the mains of the different London water companies in accordance with the intercommunication scheme. The meters are double-ended, and so constructed that they are capable of measuring the flow of water in either direction. At the East London waterworks Leyton, England, is a "Venturi" meter measuring a flow of water at the rate of 37 million gallons per day. Fig. 32 is a view of the meter-house.

In connexion with the Staines reservoirs (London Water Supply), Mr. George Kent, London, has fitted up a cabinet (Fig. 33), to which the results given by fifteen various water-measuring instruments, situated at different parts of the works, are electrically conveyed, and the system of water measurement here is probably the most complete in the world.

In the case of many towns in this country the water supply is obtained either wholly or in part from underground sources, and improved methods have been devised for sinking borings of from 3 inches up to about 2 ft. 6 in. diameter to depths of several hundreds of feet, or as may be found necessary. Many firms have made a speciality of this branch of water-supply work, amongst whom are Messrs. C. Isler & Co., Le Grand & Sutcliff, Duke & Ockenden, Chapman & Son, Richards & Co., J. Warner & Sons,

J. C. Thom, and Mather & Platt, Ltd. Fig. 34 is a view of a "round rope boring machine," and Fig. 35 of a "flat rope boring machine," as used by Messrs. Mather & Platt, Ltd., of Manchester. A set of the various tools, as made by Messrs. R. Richards & Co., used in sinking borings of this class, are shown in Fig. 36.

In a boring sunk for the Great Northern Railway Co., at Werrington, near Peterborough Station, by Messrs. Le Grand & Sutcliff, a supply of 300,000 gallons per day was obtained at a depth of 132 ft. from the Lincolnshire limestone, under an artesian head of 20 ft., as is illustrated in the photograph (Fig. 37). At Bourne, Lincolnshire, an artesian well bored by Messrs. Isler & Co. yielded an overflow at the rate of 5 million gallons per day for the town supply of Spalding, as shown in Fig. 39, which also illustrates that firm's plant and mode of operations in boring. The view (Fig. 38) shows the extraordinary effect of a shot fired in hard rocks at the depth of 363 ft. from the surface in a 7¼-in. internal diameter artesian bored tube well sunk by Messrs. C. Isler & Co. for Messrs. Arnold, Perrett & Co., The Brewery, Wickwar, Gloucester.

For raising water from these deep borings the "air-lift system," or raising by compressed air, is now being largely adopted. Fig. 40 is a view of two horizontal compound steam engines and double-stage air compressors put down at the Tunbridge Wells Corporation waterworks by Messrs. Hughes & Lancaster, of Ruabon, for the purpose of working an air-lift in a 15 inch dia: borewell, and from which a discharge of over 30,000 gallons per hour is obtained, or at least 60 per cent. more than could be got in this case by the ordinary deep-well pump.

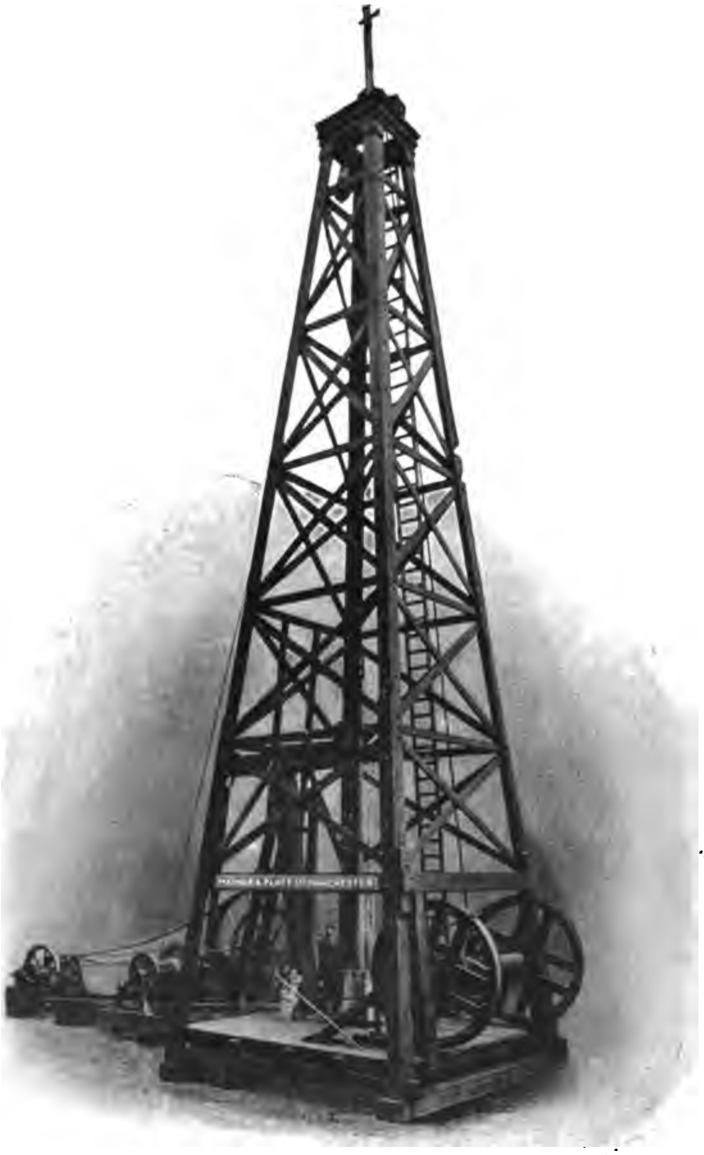


FIG. 34.—ROUND-ROPE BORING MACHINE (MATHER AND PLATT, LTD.)

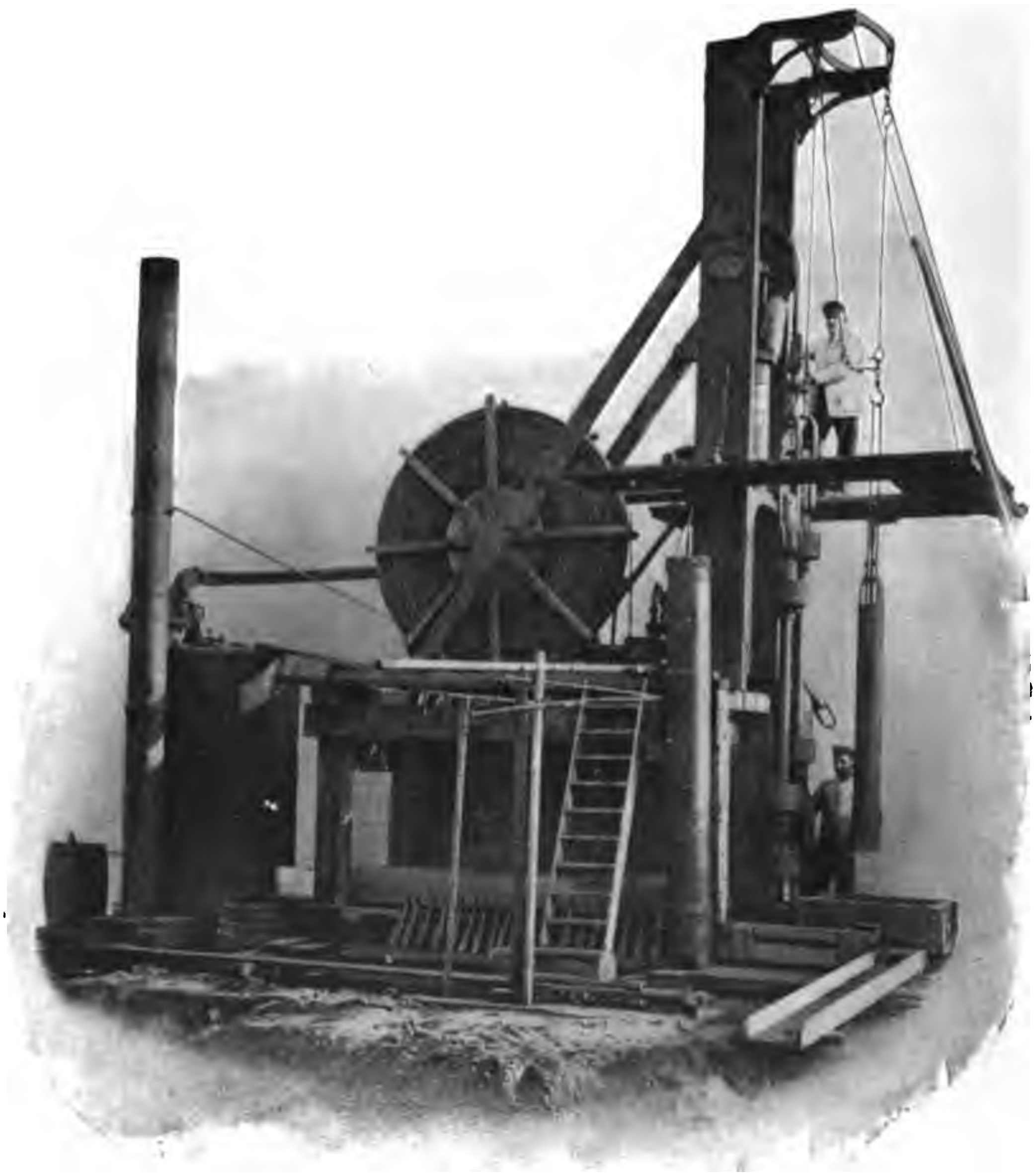


FIG. 35.—FLAT-ROPE BORING MACHINE (MATHER AND PLATT, LTD.).

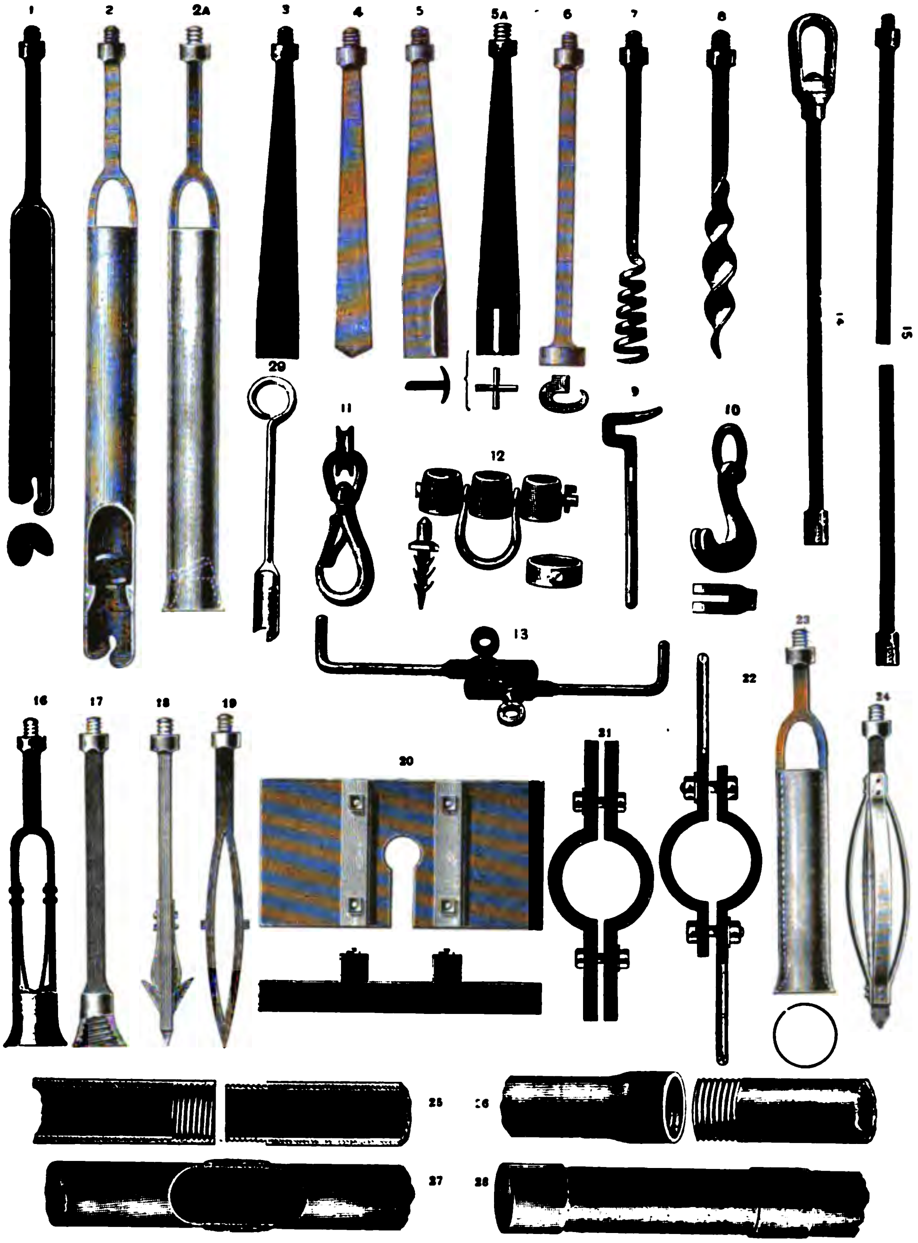


FIG. 36.—SET OF BORING TOOLS (R. RICHARDS AND CO.).

1. Clay Auger, for clay and stiff soils. 2. Auger Nose Shell, with Valve, for bringing up loose and saturated strata from bore holes. 2A. Shoe ditto. 3. Flat Chisel, for moderately hard ground. 4. V ditto. 5. Tee Chisel, for hard and rocky strata. 5A. X ditto. 6 Crow's Foot, for drawing broken rods. 7. Spiral Worm, ditto. 8. Worm Auger, for loosening strata in bore holes. 9. Hand Dog or Rod Wrench. 10. Lifting Dog, for raising rods. 11. Spring Hook. 12. Ironwork for Shear Legs. 13. Tillers, for working rods. 14. Swivel Top Rod. 15. Well Rod or Boring Rod. 16. Bell Box, for extracting broken rods or tools. 17. Bell Screw for ditto. 18. Spring Dart, for drawing out pipes. 19. Lowering Tee, for lowering one set of pipes through another. 20. Auger or Dog Board. 21. Pipe Clamps, for screwing pipes together. 22. Pipe Tillers, for ditto. 23. Circular Chisel, for trimming down bore hole true and vertical. 24. Cutting Springs, for enlarging bore hole below lining tubes. 25. Flush Jointed Lining Tubes. 26. Swelled ditto. 27. Steel Socketted Lining Tubes. 28. Rivetted or Brazed ditto. 29. Auger Clearer.

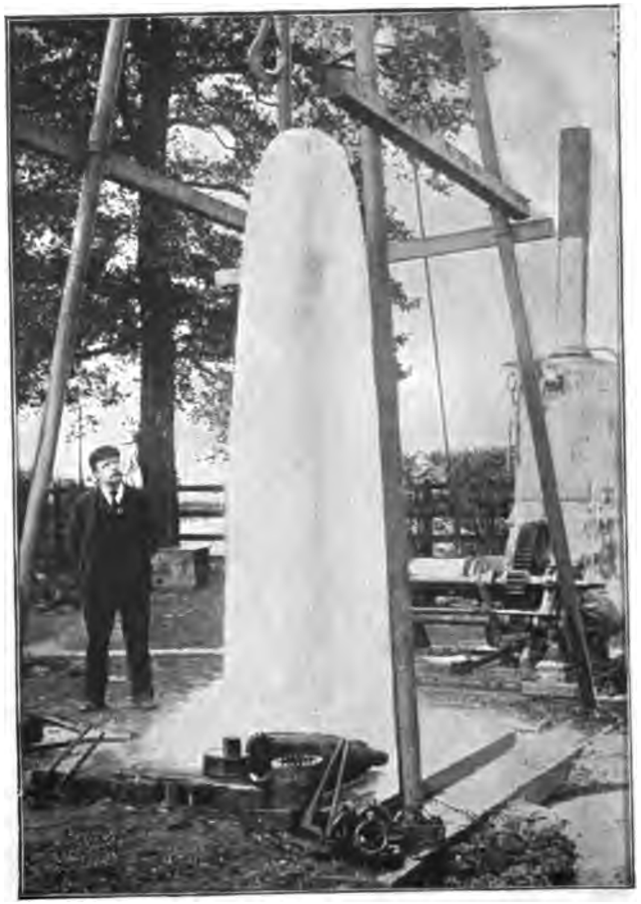


FIG. 37.—ARTESIAN HEAD AT BORING FOR GREAT NORTHERN RAILWAY, WERRINGTON, BY LE GRAND AND SUTCLIFF.

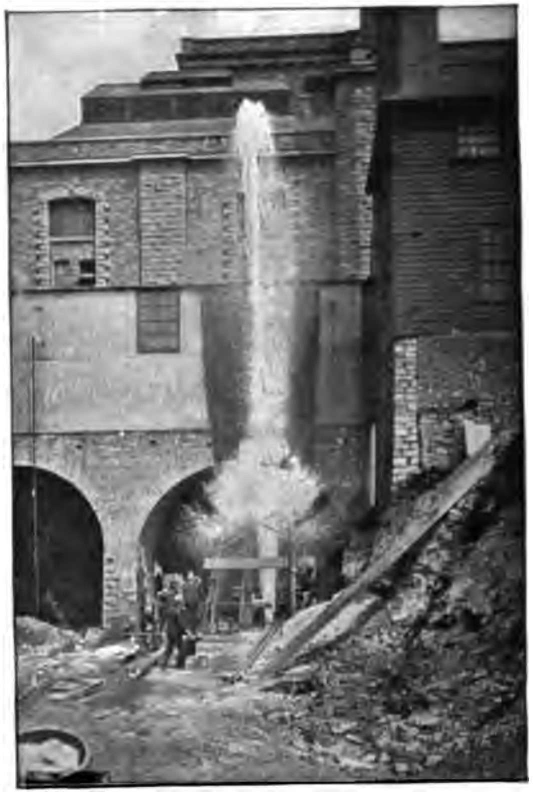


FIG. 38.—EXTRAORDINARAY EFFECT OF A SHOT FIRED AT 363 FEET FROM SURFACE IN A BORING BY C. ISLER AND CO.

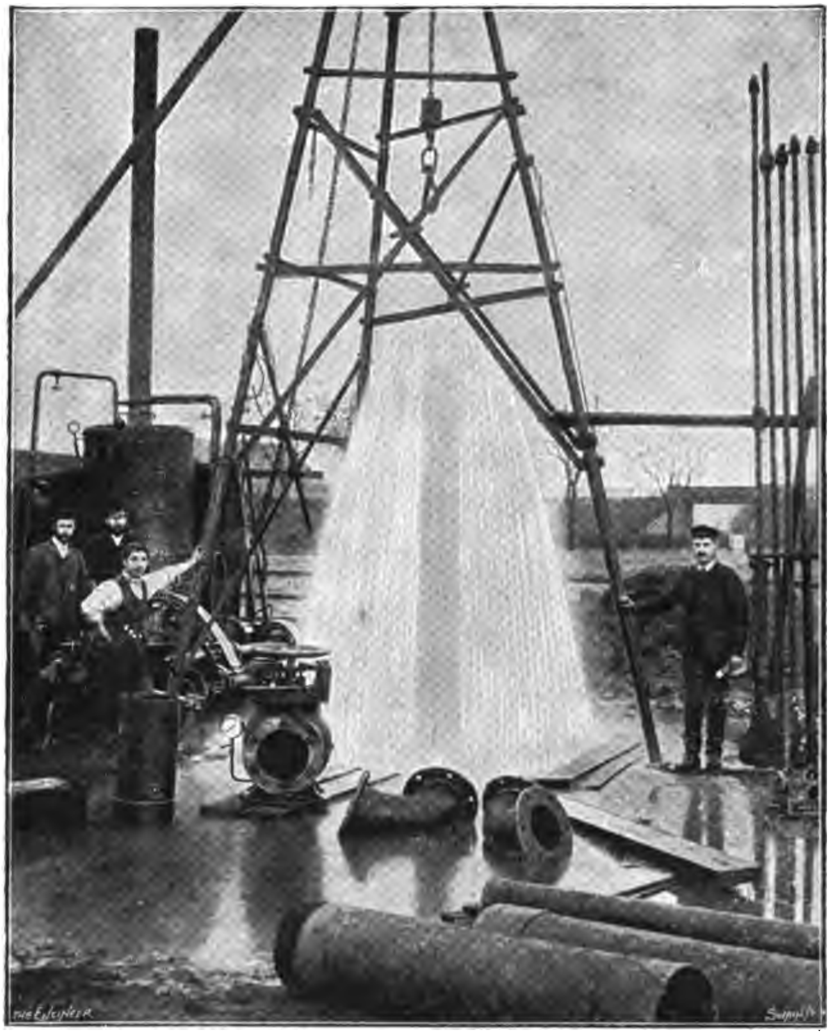


FIG. 39.—OVERFLOW AT BOURNE BORING, SUNK BY C. ISLER AND CO.

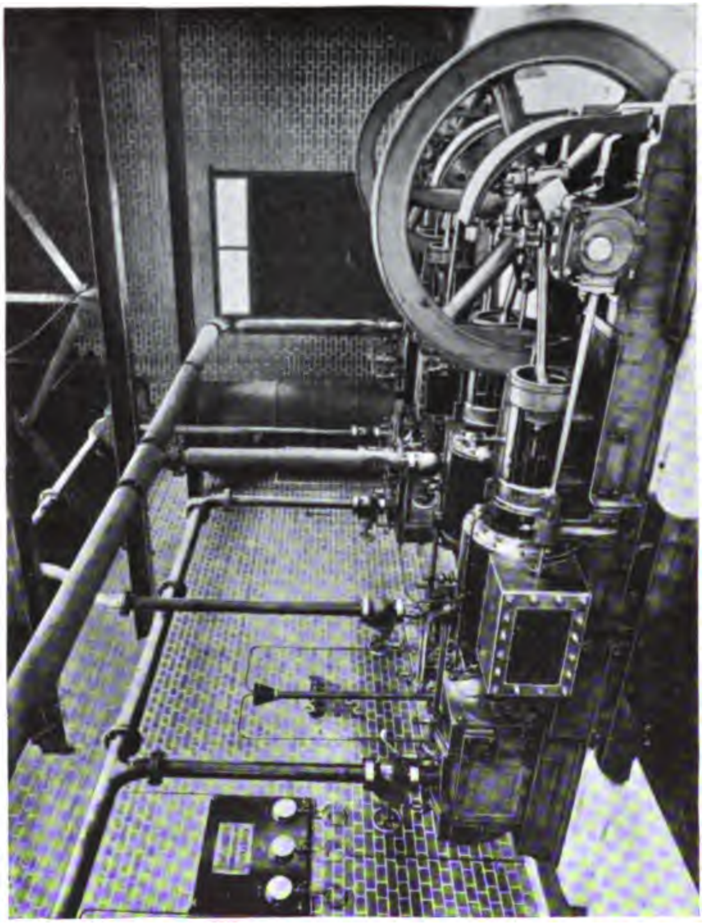


FIG. 40.—COMPOUND AIR COMPRESSORS; TUNBRIDGE WELLS CORPORATION "AIR-LIFT."

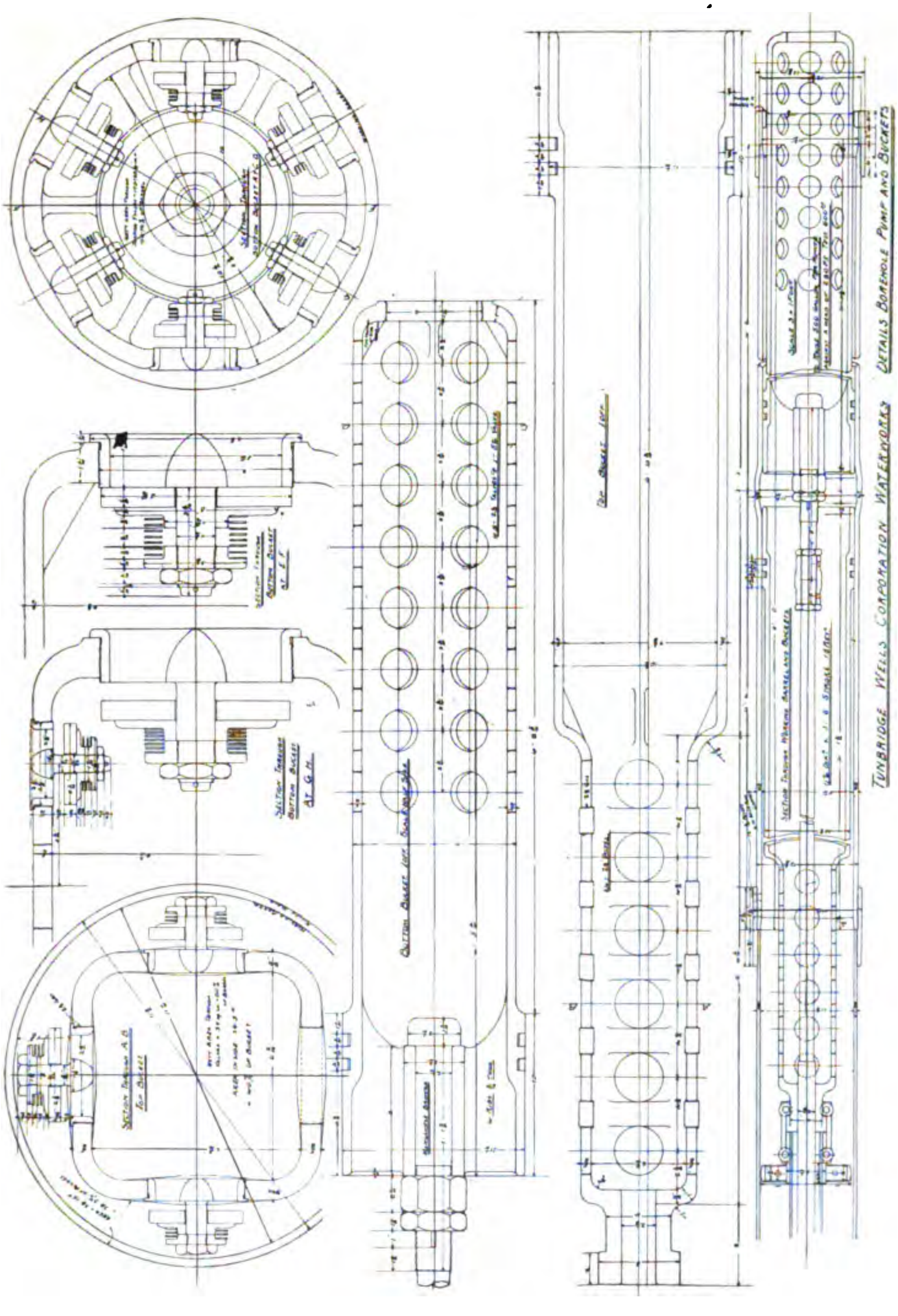

TUNBRIDGE WELLS CORPORATION WATERWORKS
DETAILS BOREHOLE PUMP AND BUCKETS
Section through Bottom Bucket at E.F.
Section through Bottom Bucket at G.H.
Section through A.B. Top Bucket
Bottom Bucket 1/4 Full Size
Top Bucket 1/4 Full Size

FIG. 41.—DOUBLE-ACTING "ASHLEY" BOREWELL PUMP, AS SUPPLIED BY GLENFIELD AND KENNEDY TO A DEEP BORING AT TUNBRIDGE WELLS CORPORATION WATERWORKS.

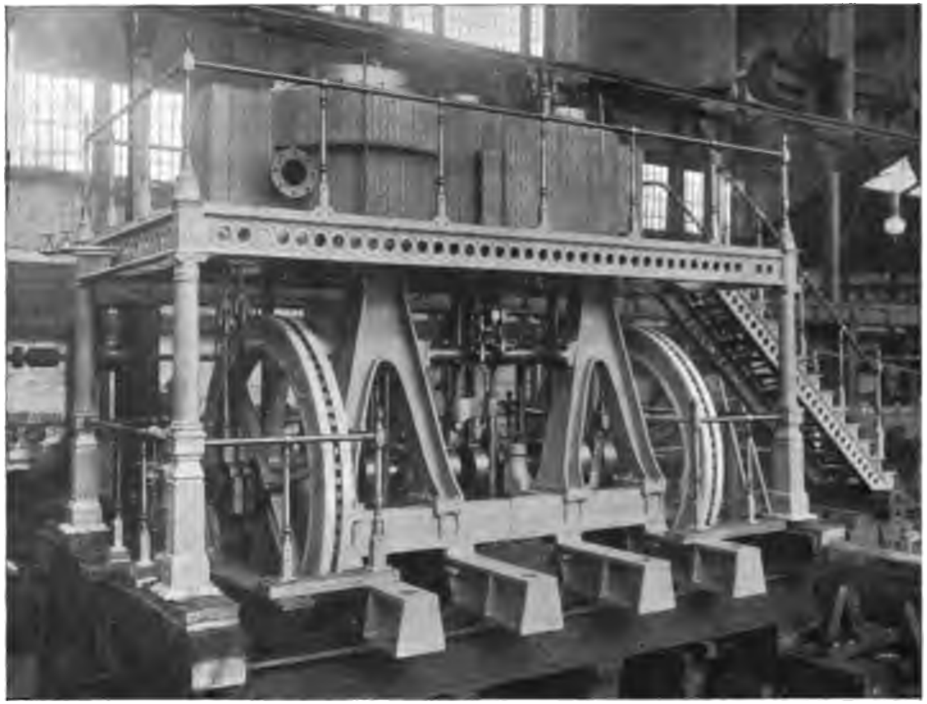


FIG. 42.—TRIPLE EXPANSION INVERTED CYLINDER TYPE ENGINES AT SWITHLAND RESERVOIR, LEICESTER CORPORATION WATERWORKS. (EASTON, ANDERSON & GOOLDEN, LTD.)

A good type of steam-driven pump well suited to bore-well work is the "Ashley" pump made by Messrs. Glenfield & Kennedy, of Kilmarnock. Fig. 41 shows details of a double-acting pump of this type installed, under my direction, in a 15 inch by 350-ft. boring, at the Tunbridge Wells Corporation waterworks, to discharge 500 gallons per minute.

Of heavy modern waterworks steam-pumping machinery of the highest order Great Britain possesses many first-class makers, whose names, through the excellence of their productions, are well-known in almost every part of the commercial world. It is not intended, however, here to deal with this branch of the subject in detail, as it is of such importance as to call for special treatment in a lecture devoted entirely thereto. This task has been carried out by Mr. Bjorling in his lecture on " Pumps and Pumping Engines " in connexion with the present series, and to which reference should be made.

I shall here, therefore, only attempt a very general reference to a few leading typical examples of British productions in this connexion, in order to indicate briefly something of the great progress made both in the design and economy of working of pumping machinery in this important branch of water engineering.

The plant illustrated in Fig. 42 was installed by Messrs. Easton, Anderson, & Goolden, Ltd., at the Swithland reservoir pumping station of the Leicester Corporation waterworks in 1898.

The engines are of the triple-expansion inverted cylinder type, having cylinders 17, 27, and 44 in. in diameter respectively. The stroke is 3 ft., and the steam pressure 120 lb. per square inch. There are three pumps of the plunger type situated beneath the cylinders, the plungers, 12½ in. diameter by 3 ft. stroke, being coupled direct to the crossheads of the engines. The connecting rods are pivoted at the bottom ends of the pump plungers and actuate a crank shaft having cranks set at an angle of 120° to one another. There is a surface condenser fitted to each engine, having a cooling area of 298 square feet, the circulating pump water passing through the tubes. The ordinary working speed is 25 revolutions per minute, but the engines are designed to work up to a maximum speed of 30 revolutions.

These engines, of which there are two, under ordinary working conditions, upon trial, gave a fuel consumption per indicated horse power per hour of 1·44 lb., and developed about 140 indicated horse power each. The average steam consumption was 13·36 lb. per indicated horse power per hour, and the mechanical efficiency of the engines 88·6 per cent. The average duty in weight of water lifted per 112 lb. of coal consumed, reduced to an evaporation of 10lb. of water per lb. of coal, was 137·83 million foot-lbs. of work.

Figs. 43 and 44 show a set (made in duplicate) of compound Corliss surface-condensing pumping engines constructed by Messrs. R. Moreland & Son, Ltd., London, for the New River Water Company. The capacity of the plant is 3 million gallons of water raised 197 ft. in 24 hours.

The steam cylinders are 23 in. and 46 in. by 48 in., the pumps 21 in. by 48 in., the speed of the engines 18 revolutions per minute, and the steam pressure 110 lb. per square inch. Fig. 45 shows a plant of 1,300 horse power direct-acting compound pumping engines of 18 million gallons capacity per 24 hours, erected for the Southwark and Vauxhall Water Company at Hampton, London, also by Messrs. R. Moreland & Son.

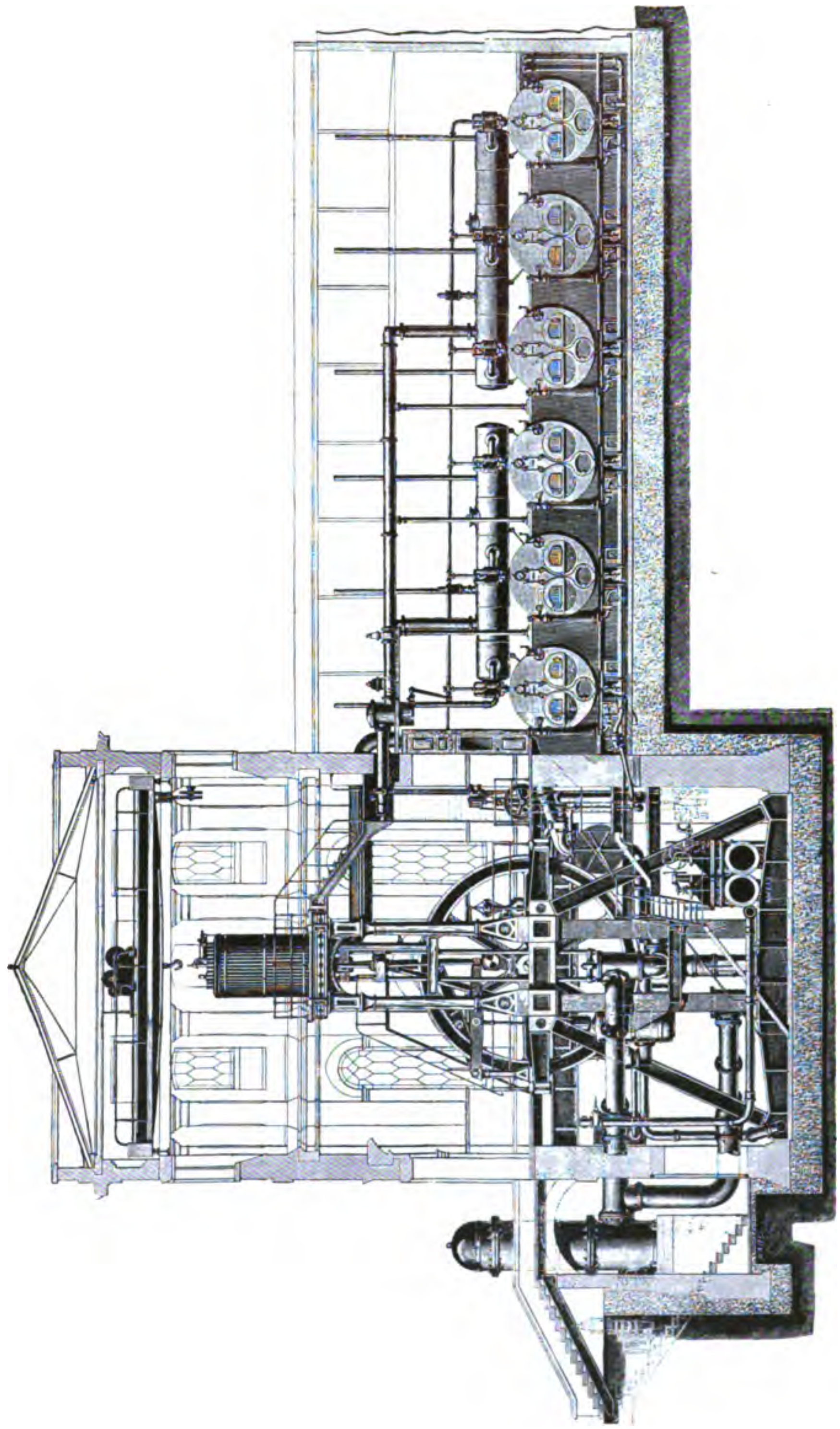


FIG. 45.—1,300 H.P. PLANT AT SOUTHWARK AND VAUXHALL WATERWORKS, HAMPTON (R. MORELAND AND SON, LTD.).

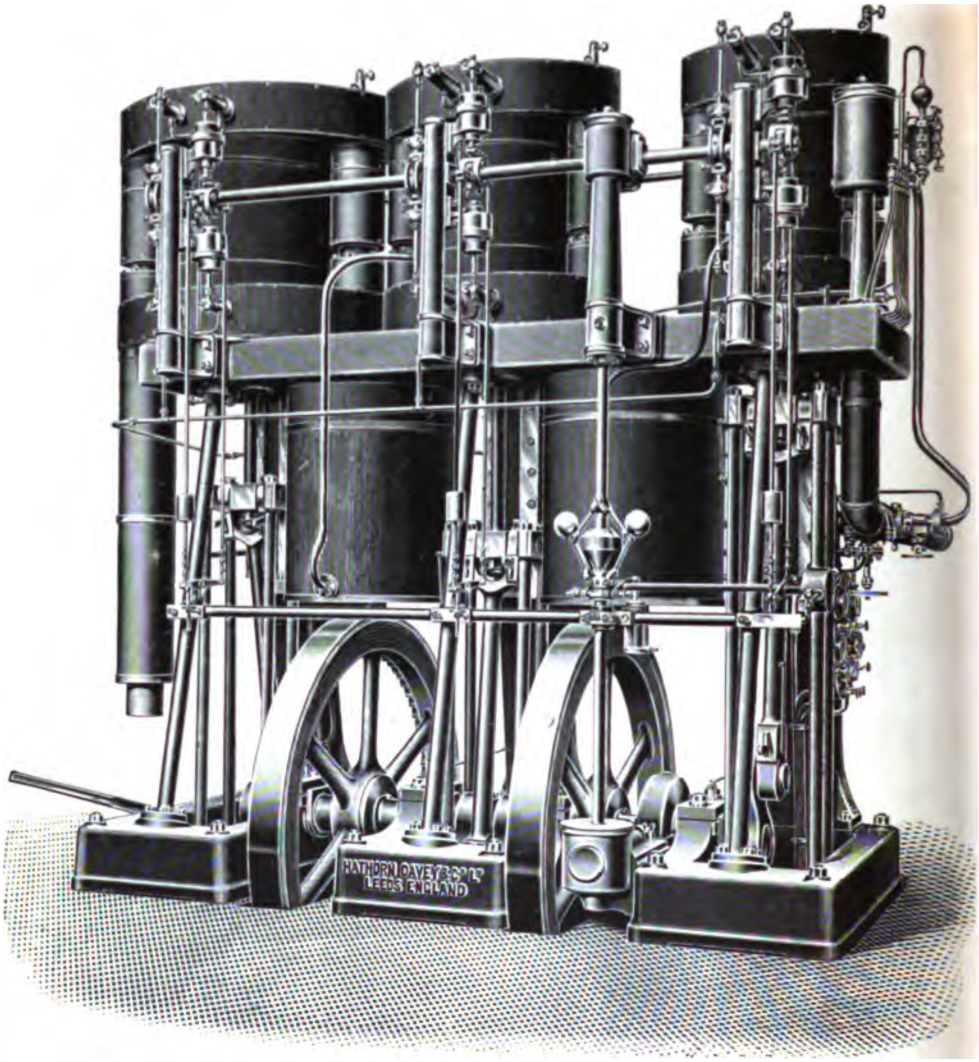
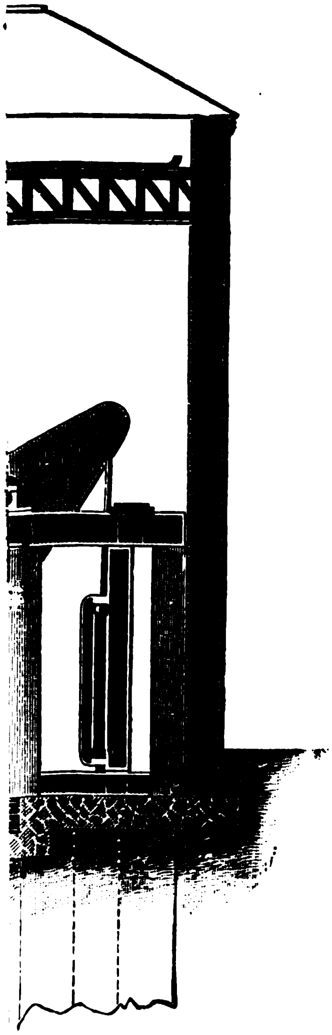
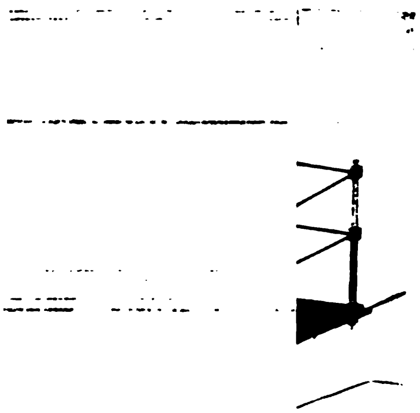


FIG. 46.—LATEST TYPE VERTICAL ROTATIVE TRIPLE EXPANSION PUMPING ENGINE, LEEDS CITY WATERWORKS (HATHORN, DAVEY AND CO.).





KENNEDY).

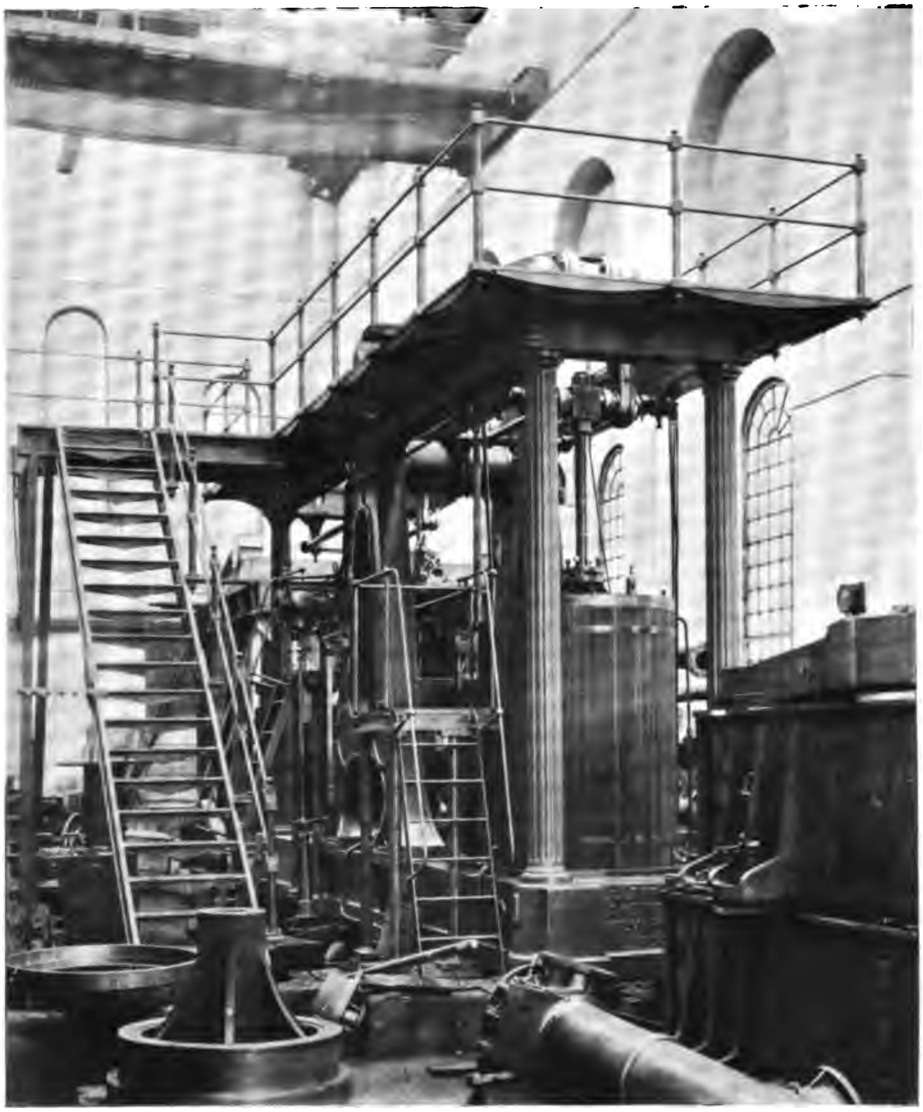


FIG. 48.—BEAM ENGINE FOR MID-KENT WATERWORKS, ERECTED 1900 (GLENFIELD AND KENNEDY).

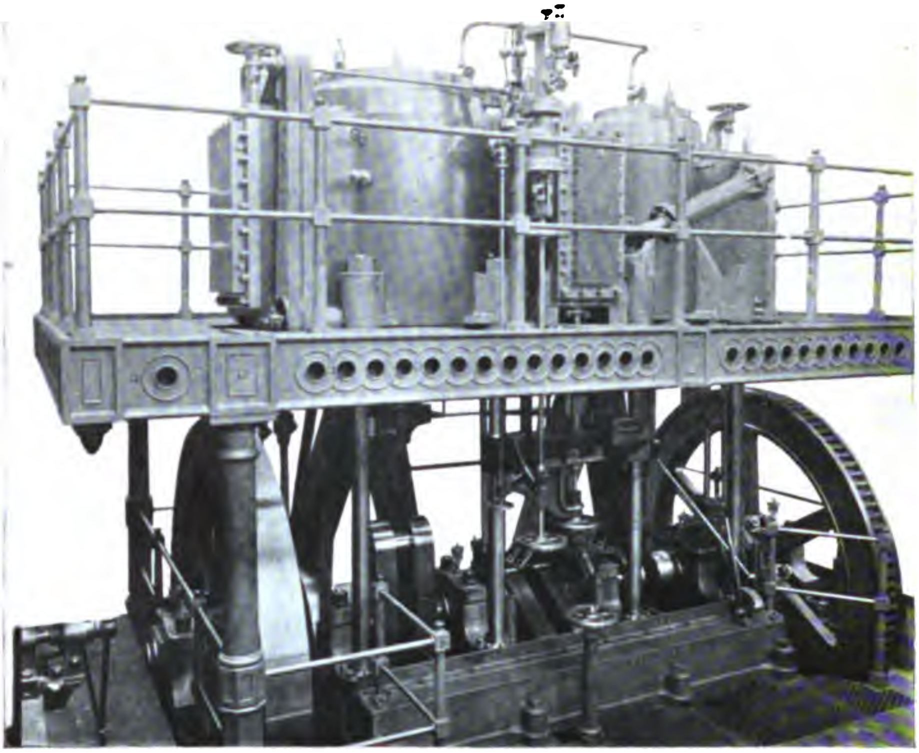


FIG. 49.—TRIPLE EXPANSION ENGINE AT FRANKLEY RESERVOIR, BIRMINGHAM CORPORATION WATERWORKS (GLENFIELD AND KENNEDY).

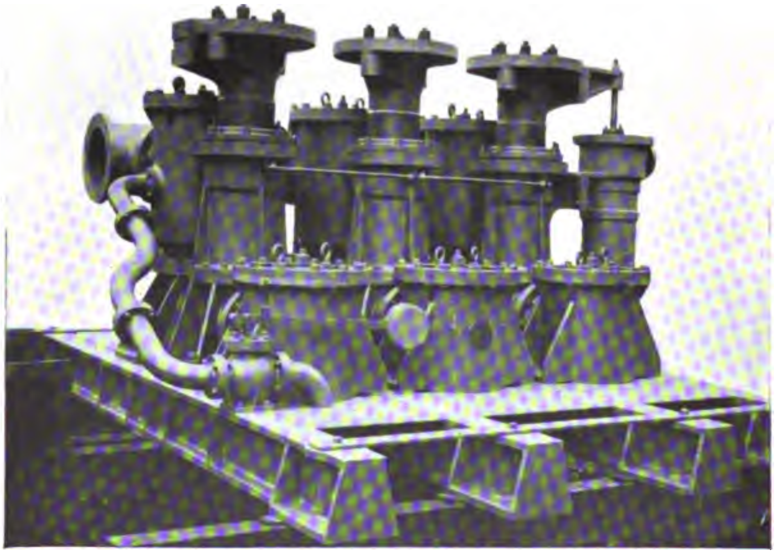


FIG. 50.—THREE RAM PUMPS FOR BIRMINGHAM CORPORATION WATERWORKS (GLENFIELD AND KENNEDY).

The illustration (Fig. 46) shows Messrs. Hathorn, Davey & Company's latest type vertical, rotative, triple-expansion Corliss pumping engine, working single-acting ram-pumps directly attached to the engine piston-rods. A pair of engines of this class were supplied to the Leeds City waterworks, each to raise 1⅓ million gallons of water in 12 hours through 3¾ miles of 18-inch pipes having a rise of 260 ft. One of these engines upon test gave an efficiency of 91·3 per cent., and was found to have a steam consumption of 13·05 lb. per actual horse-power in water lifted per hour. A similar engine supplied to the Melbourne Corporation in 1900 gave an efficiency of 92·8 per cent., with a steam consumption of 13·5 lb. per actual horse power per hour in water lifted, and another engine of the same type supplied to the Odessa Municipality in 1899 gave a steam consumption of 12·44 lb. per pump horse-power hour.

The arrangement of plant given in Fig. 47 shows Messrs. Hathorn, Davey & Company's horizontal compound differential pumping engine, as supplied in 1892 to the Widnes Waterworks, for the purpose of raising 1,560 gallons of water per minute from bore-holes 200 feet deep, and forcing this water forward through a further lift of 260 feet, give 32-in. and 60-in. cylinders by 6 ft. 3-in. stroke, and works a pair of 18½-in. diameter lift pumps in the bore-holes, of 6 feet 6 in. stroke. These pumps deliver the water into a sump under the engine-room floor, and from which a double-acting piston force-pump, 18½ inches diameter by 6 ft. 3 in. stroke, takes the water and forces it to the reservoir.

Upon an official trial this plant gave a duty of 109·6 million foot-pounds of work on 1,008 lbs. of steam, or on 112 lbs. of coal evaporating 9 lbs. of water per 1 lb. of coal. The indicated H.P. was 230, the pump H.P. 200, and the mechanical efficiency 87 per cent. The steam consumed per indicated H.P. per hour was 15·6 lbs., and 18 lbs. per pump H.P.

The pumping engine shown in Fig. 48 is a beam engine constructed in 1900 by Messrs. Glenfield & Kennedy for the Mid-Kent waterworks. The h.p. cylinder is 28 in. diameter by 3 ft. stroke, and the l.p. cylinder 38 in. diameter by 5 ft. stroke; the speed is 16 revolutions per minute, and the boiler pressure 100 lb. The well pumps are 12 in. diameter by 5 ft. stroke, and the head 225 ft. The ram pumps are 11 in. diameter by 3 ft. stroke, and the head 410 ft.

A triple-expansion engine by Messrs. Glenfield & Kennedy put down in the year 1900 for the Birmingham Corporation waterworks at the Frankley reservoir is shown in Fig. 49. The cylinders are 13 in., 20¼ in., and 32 in. diameter respectively, by 3 ft. stroke. The steam pressure is 150 lb. to the square inch, and the speed 25 revolutions per minute.

The illustration, Fig 50, shows three ram pumps by Glenfield & Kennedy for the Birmingham Corporation waterworks. The pumps are 12 in. diameter by 3 ft. stroke, and deliver 1,050 gallons per minute to the total head of 240 ft.

A horizontal coupled compound pumping engine put down in 1897 by Glenfield Company, Ltd., for the Accrington waterworks is illustrated in Fig. 51. The cylinders

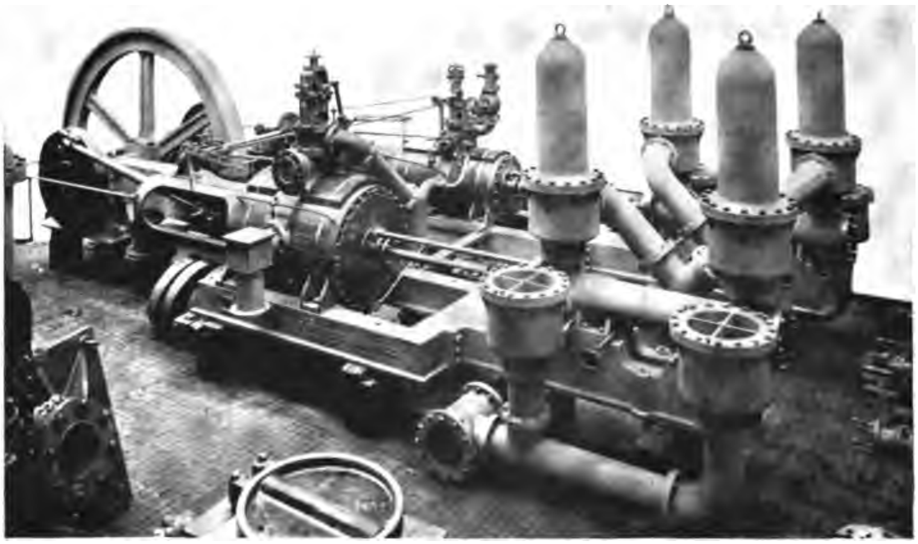


FIG. 51.—HORIZONTAL COUPLED COMPOUND PUMPING ENGINE (1897) AT ACCRINGTON WATERWORKS (GLENFIELD CO., LTD.).

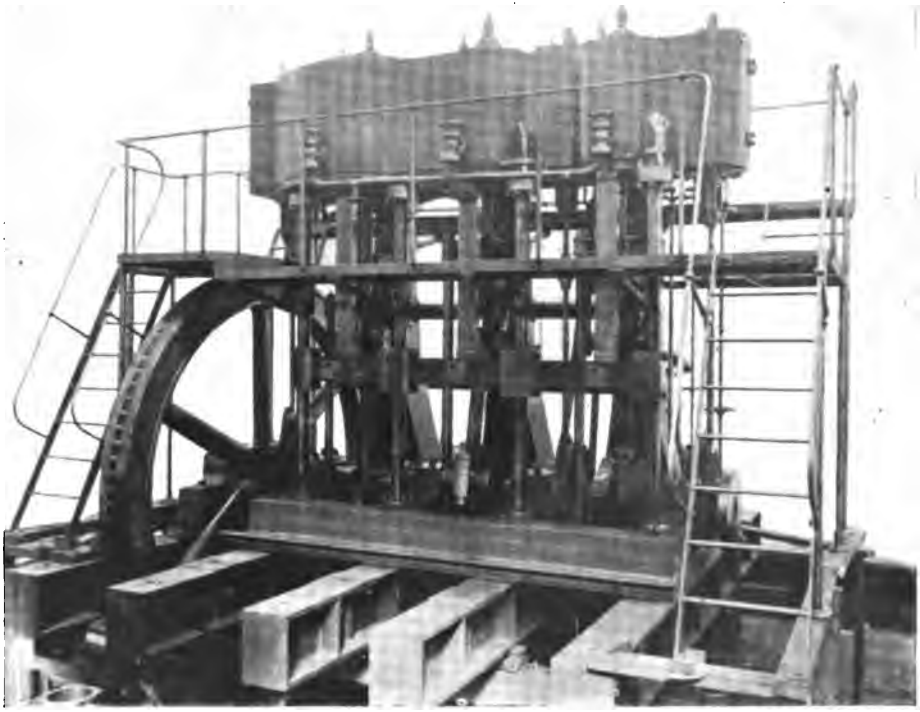


FIG. 52.—TRIPLE EXPANSION ENGINE (1898), FOR THE CITY OF PERTH WATERWORKS (GLENFIELD CO., LTD.).

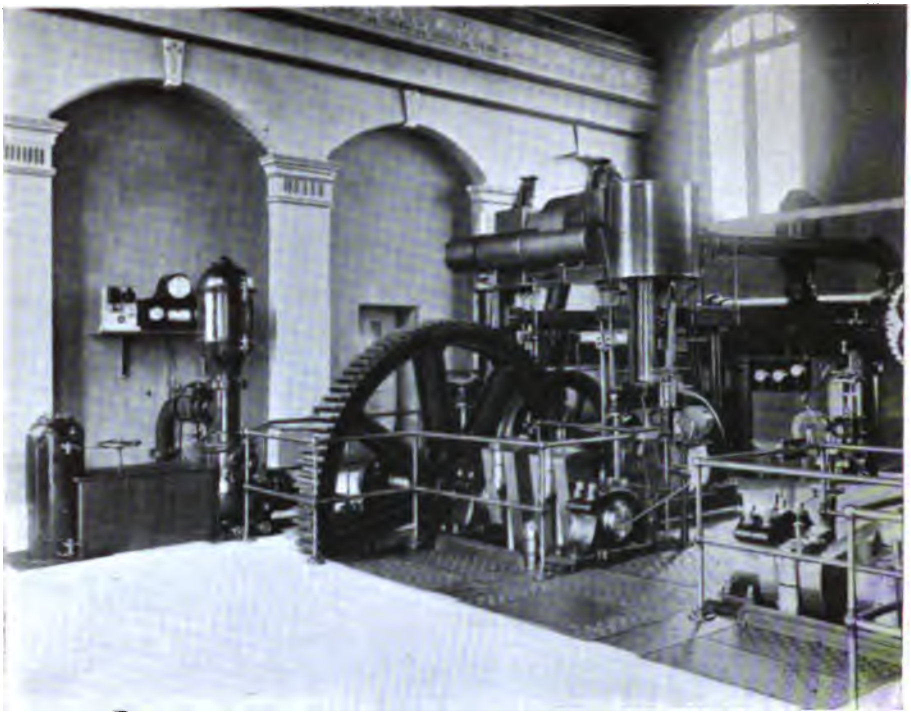


FIG. 53.—PUMPING MACHINERY AT WINGHAM, MARGATE NEW WATERWORKS (J. SIMPSON AND CO., LTD.).

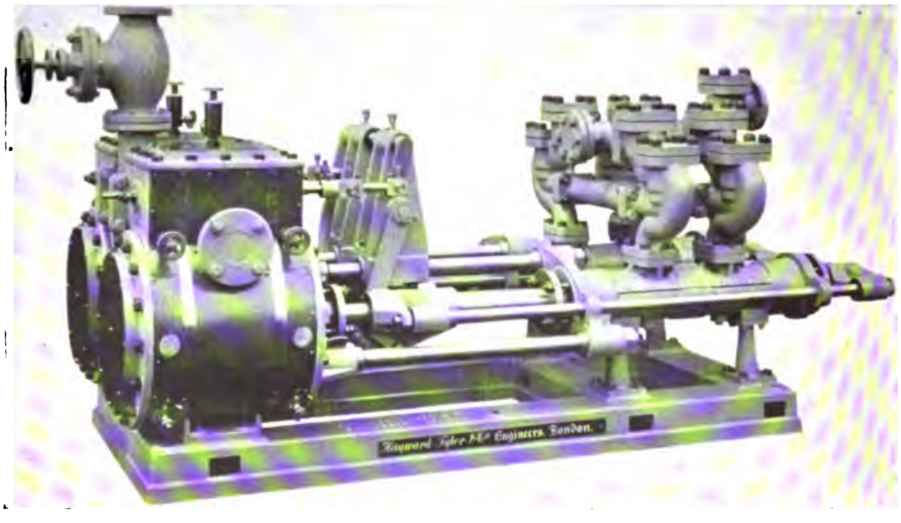


FIG. 54.—COMPOUND DUPLEX PUMPING ENGINE, WINDSOR CORPORATION WATERWORKS (HAYWARD-TYLER AND CO.).

are 18 in. and 35 in. diameter by 42 in. stroke, and the pumps 10 in. diameter by 42 in. stroke; the speed is 30 revolutions per minute, the pump-horse-power 112, and the steam pressure 100 lb. to the square inch. The delivery is 1,360 gallons per minute against a head of 270 ft.

A triple-expansion engine by the same makers, constructed in 1898 for the city of Perth waterworks, is shown in Fig. 52.

The cylinders are 14 in., 23 in., and 38 in. diameter respectively, by 24 in. stroke; the speed is 37 revolutions per minute, and the steam pressure 160 lb. The sizes and deliveries of the pumps are :—

Pump.	Diam. in inches.	Discharge in gallons per min.	Head in ft., including friction.
High level pump .	6⅝	200	422
Mid " . .	14	868	266
Low " . .	13½	810	107

The illustration, Fig. 53, shows the pump-room at Wingham, the site of the new water supply of Margate, installed in August of last year. The supply is obtained from wells and adits in the chalk, and the water is delivered into the town by means of an 18 in. cast-iron main, 14 miles in length. The supply is pumped from the wells through this main by two duplicate triple-expansion engines and pumps of 166 h.p. each. Each pump at normal speed will deliver two million gallons of water per 24 hours. The makers of the plant are Messrs. J. Simpson & Co., Ltd., Engineers, Pimlico.

A compound duplex pumping engine, by Messrs. Hayward-Tyler & Co., for the Windsor Corporation waterworks, at Tangier Island, is shown in Fig. 54. The h.p. cylinder is 12¼ in., the l.p. 19 in., the pump 12 in., and the stroke 12 in. The duty is 1¼ million gallons in 24 hours against a head of 220 feet. A high-pressure jet-condensing pumping engine by the same makers is illustrated in Fig. 55, as erected for the Hitchin waterworks. The steam cylinder is 12¼ in. by 24 in., with double-acting single-barrel piston pump 10½ in. by 12 in. placed alongside the steam cylinder, driven by the same crank-shaft, the one crank having 24 in. throw and the other 12 in. The duty is 25,000 gallons per hour against a total head of 165 feet.

Where large volumes of water have to be raised through comparatively low lifts, the centrifugal type of pump is in great favour, and a good example of this class of machinery for waterworks purposes is shown in Fig. 56, which illustrates one of a pair made by Messrs. J. & H. Gwynne, and shipped to Sydney for the New South Wales Government. This engine is capable of raising 10 million gallons of water per 24 hours to a height of 50 feet, through 2,000 feet of suction and delivery pipes 28 inches in diameter. The steam pressure in the cylinders is 150 lb. per square inch, and the exhaust steam passes to a surface condenser fixed at the back of the engine standards.

It not infrequently happens in the provision of a water supply, more particularly in connexion with supplementary and temporary works, that some form of motive power is needed which will not involve so heavy an initial outlay as would be the case with a steam plant, and which at the same time offers greater simplicity and convenience

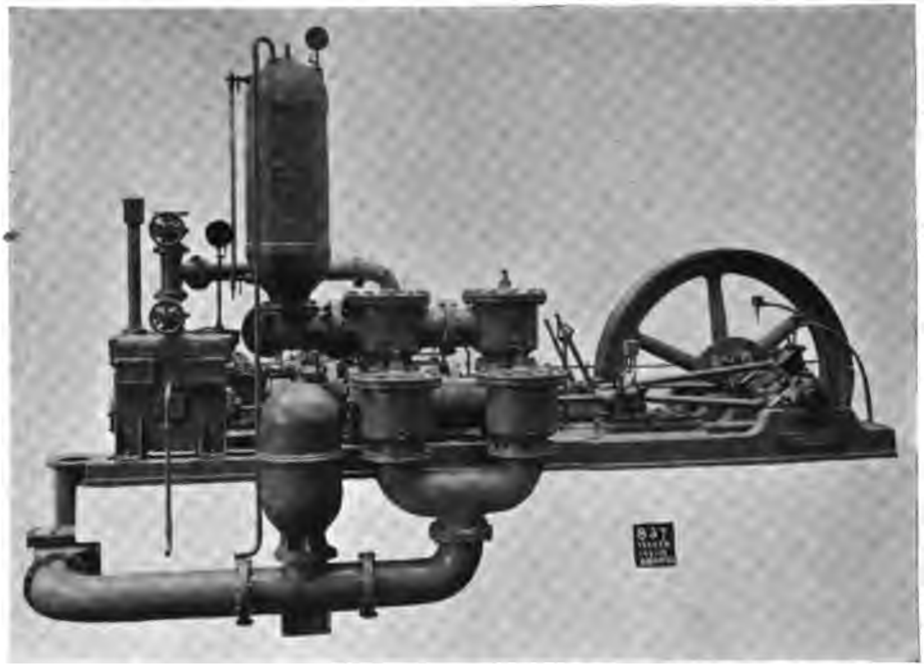


FIG. 55.—HIGH PRESSURE JET CONDENSING ENGINE AT HITCHIN WATERWORKS (HAYWARD-TYLER AND CO.).

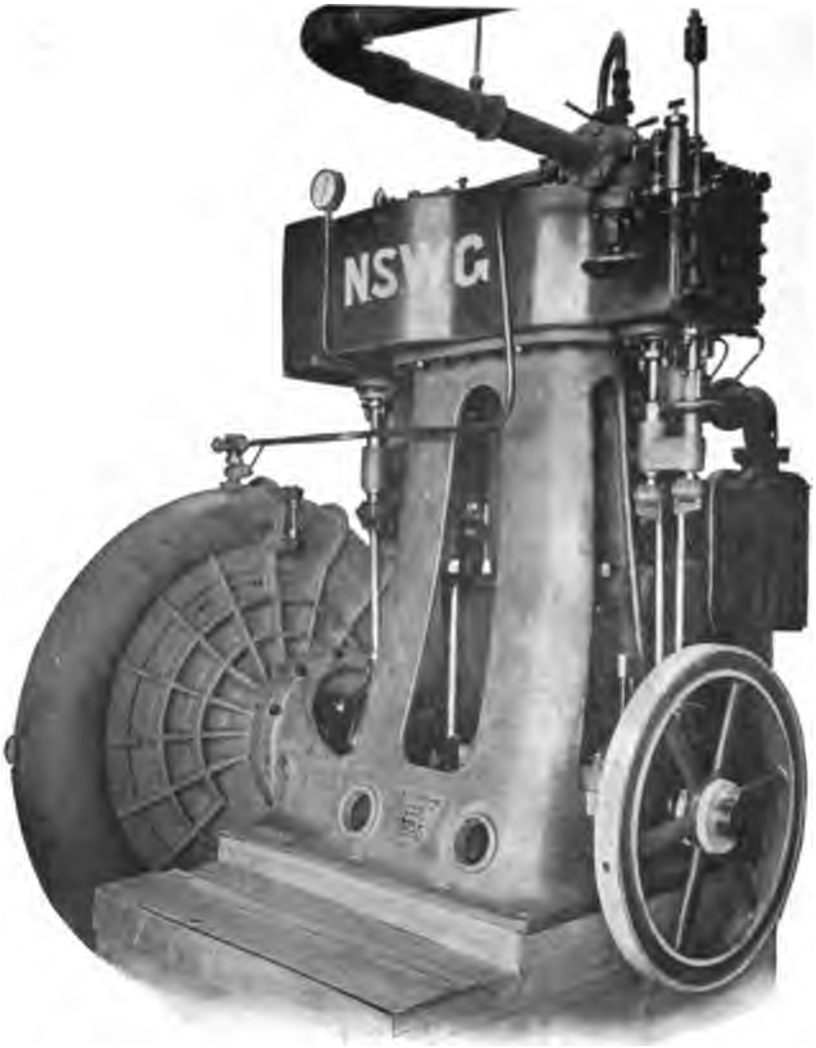


FIG. 56.—CENTRIFUGAL PUMPING MACHINERY FOR THE NEW SOUTH WALES GOVERNMENT (J. AND H. GWYNNE, LTD.).

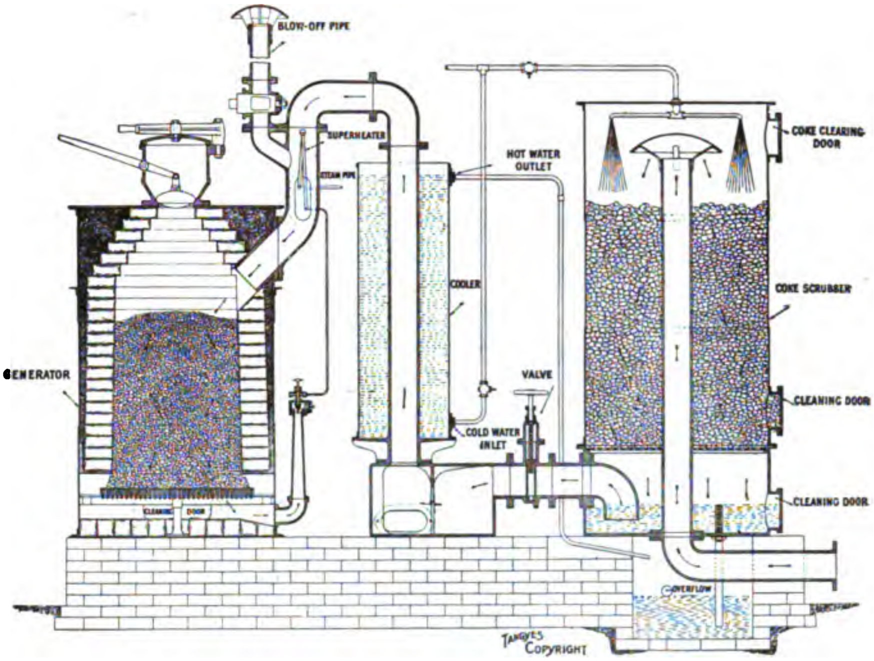


FIG. 57.—GAS PRODUCER PLANT (TANGYES LTD.).

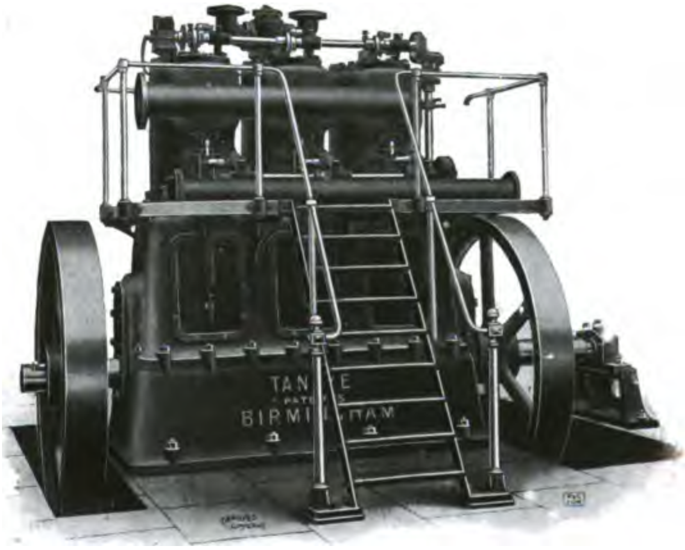


FIG. 58.—200 B.H.P. VERTICAL THREE-CYLINDER GAS ENGINE (TANGYES LTD.).

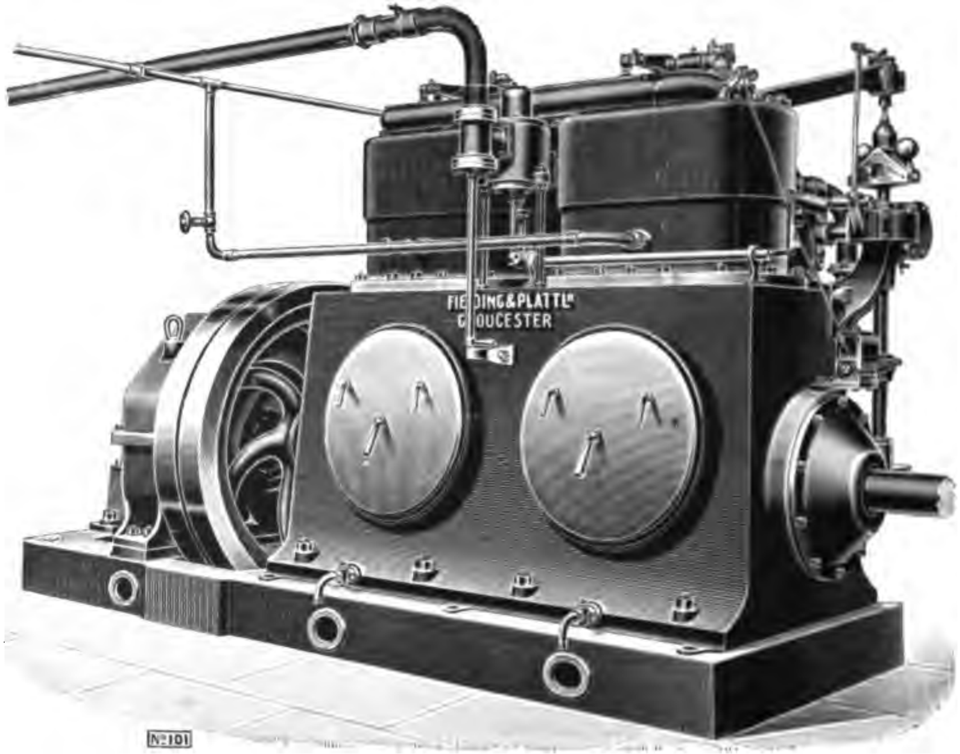


FIG. 59.—THE "FIELDING" FOUR-CYLINDER GAS ENGINE (FIELDING AND PLATT).

of working for a comparatively small and perhaps isolated plant. For such cases there are now upon the market many good designs of gas and oil engines well suited for economical pumping purposes of this description, and of late years great improvements have been made towards perfecting this class of motive power. In engines fed from the town gas supply the guaranteed consumption is now usually from 15 to 20 cubic feet per indicated horse power per hour, according to the size of engine and quality of the gas. In the larger engines, however, notwithstanding the improvements made in economy of gas consumption, the price of the ordinary town gas supply is frequently too high to permit of its use to advantage except when working intermittently. In such circumstances, and where the ordinary gas is not available, a "gas producer" plant (Fig. 57) may be adopted, giving a non-illuminating gas costing from 2¼*d*. to 4*d*. per 1,000 cubic feet. The plant illustrated is by Messrs. Tangyes, Ltd., and consists of a steel-cased generator lined with fire-bricks, a boiler of the vertical type, a cooler, dust box and scrubber, and a holder made of mild steel closely riveted. This plant will work with Welsh anthracite coal, at full load, from ¾ lb. per indicated h.p. per hour for the larger size gas engines to 1¼ lb. per i.h.p. per hour, for the smaller sizes. Or, with washed gas coke, at full load, from 1 lb. for the larger to 1½ lb. per i.h.p. per hour for the smaller size gas engines.

The illustration, Fig. 58, shows Tangyes' 200 brake horse power vertical three-cylinder gas engine, and Fig. 59 is a view of the "Fielding" four-cylinder gas engine, by Fielding & Platt, of Gloucester, made in powers from 150 b.h.p. up to 750 b.h.p.

In oil engines the consumption is usually from ¾ to 1 pint of oil per brake h.p. per hour. A standard arrangement, showing engine, water tanks, circulating pipes, etc., is illustrated in Fig. 60. In a test of the Hornsby-Akroyd cheap-fuel oil engine at the Grantham waterworks, at which I was present, the consumption of Texas crude oil was ·744 pint per b.h.p. hour, and the fuel-cost per million foot-pounds of water raised was ·183*d*.

In concluding this brief sketch of the subject of Water Supply I will refer to a few miscellaneous matters of importance which do not specially fall within either of the heads already dealt with, including the gravity and pressure filters of Mather & Platt, the International System of filtration, sand-washing apparatus, and the use of expanded metal in concrete and pure bitumen sheeting in connexion with reservoir construction.

In Fig. 61 is given a section of Messrs. Mather & Platt's patent "gravity filter" as used for the purification of water for public supply or for trade purposes. As will be seen, this filter consists of a large circular iron tank, open at the top, and resting on a cast-iron chamber in which the filtered water collects before its discharge through the outlet valve. A filter 6 ft. in diameter of this description deals with about 5,000 gallons of water per hour, and thus occupies a very small space compared with its output. In both the "gravity" and the "pressure" filter the filtering medium consists of pure quartz crystals crushed and graded to suitable sizes, the sterilization of which

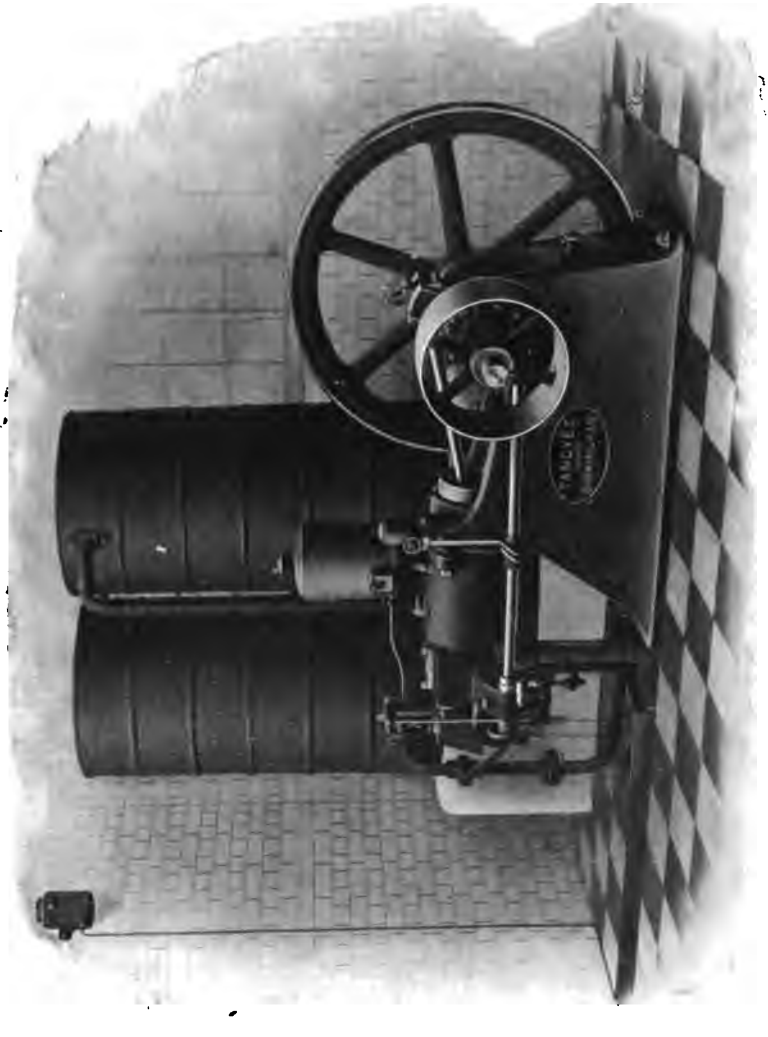


FIG. 60.—TANGYES' STANDARD ARRANGEMENT OF OIL ENGINE PLANT.

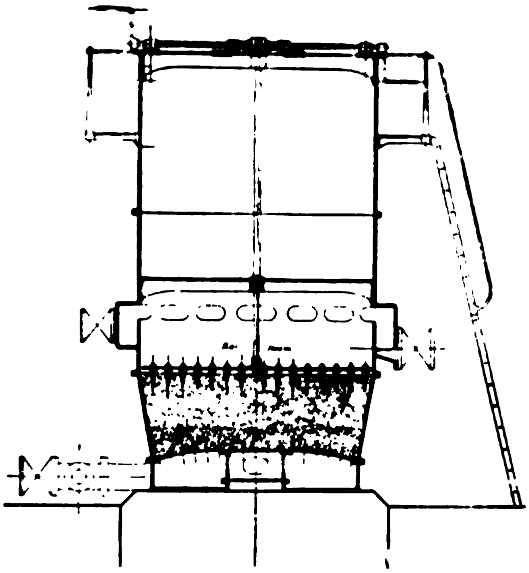


FIG. 61.—GRAVITY FILTER (MATHER AND PLATT.)

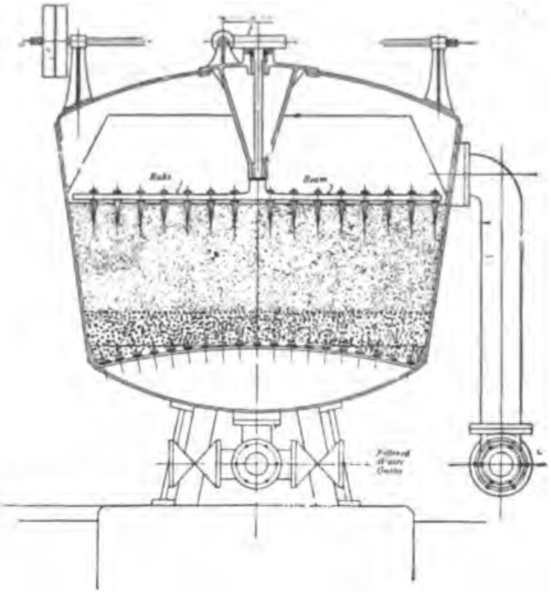


FIG. 62.—PRESSURE FILTER (MATHER AND PLATT).

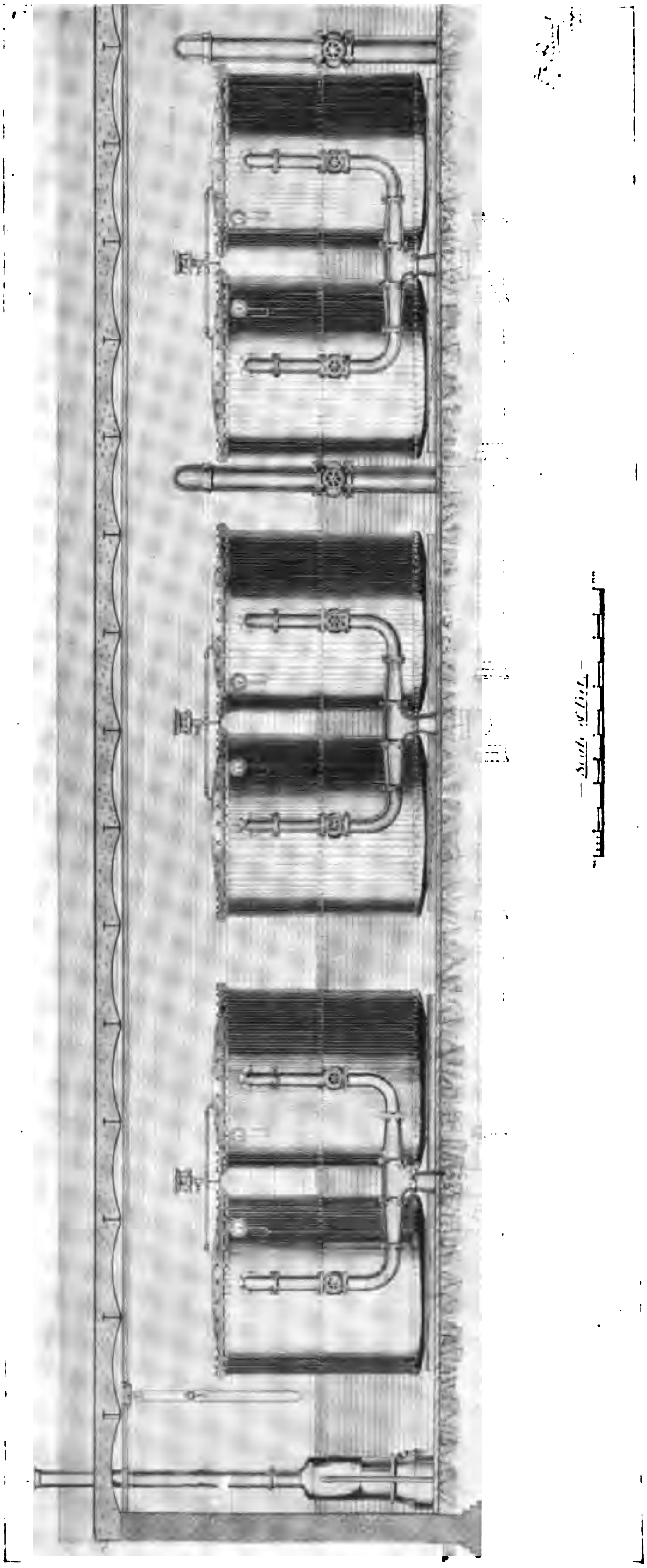
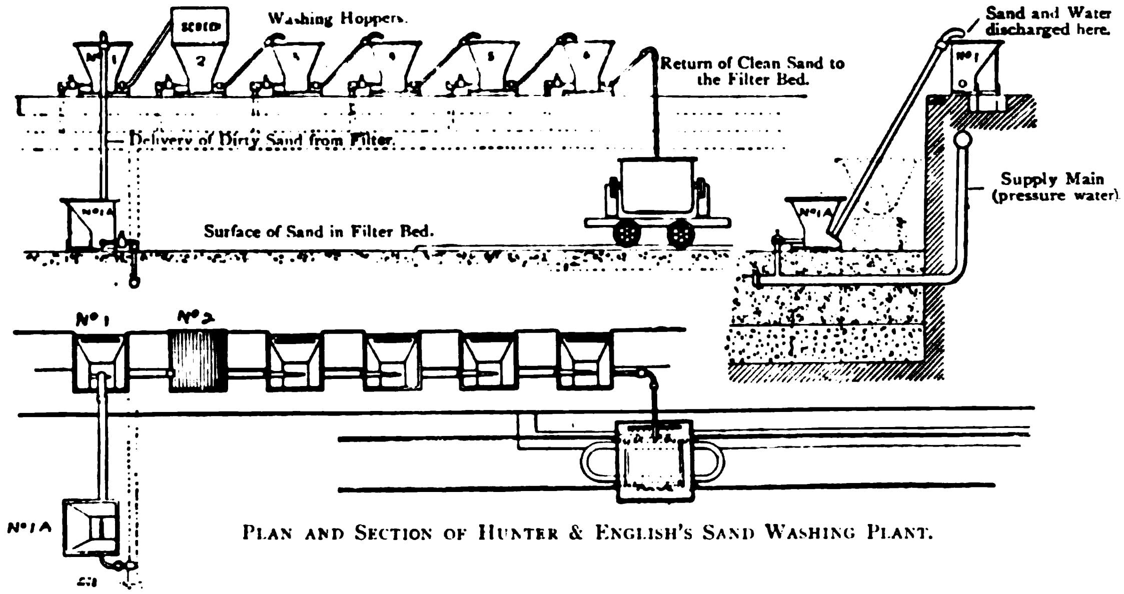


FIG. 63.—"HASTINGS" POLARITE PRESSURE FILTERS (F. CANDY).


Washing Hoppers.
Return of Clean Sand to the Filter Bed.
Delivery of Dirty Sand from Filter.
Surface of Sand in Filter Bed.
Sand and Water discharged here.
Supply Main (pressure water)
N°1
N°2
N°1A

PLAN AND SECTION OF HUNTER & ENGLISH'S SAND WASHING PLANT.

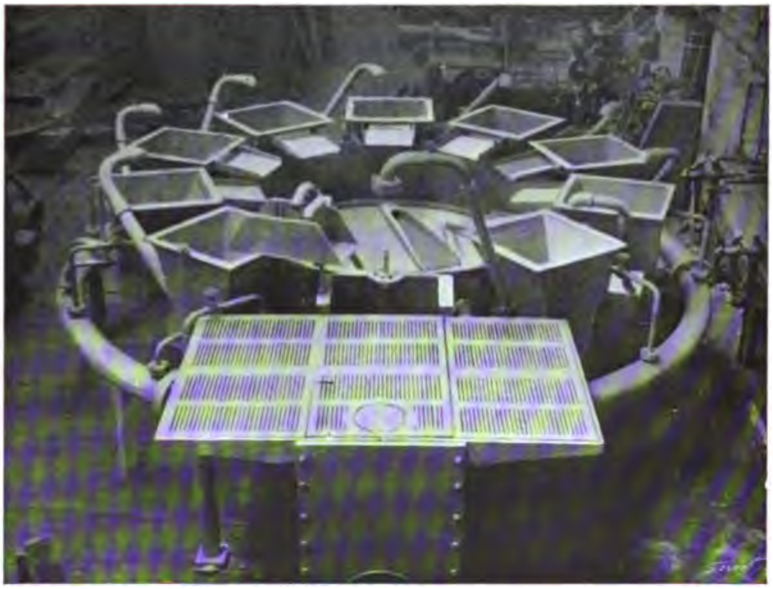


FIG. 64.—SAND WASHING PLANTS (HUNTER AND ENGLISH).
(Same principle as above arranged on a compact site).

material is readily affected after washing out, by forcing live steam through the beds, and thus destroying all animal and vegetable germs.

The "pressure filter" (Fig. 62) is specially intended for use where the filtered water is to be delivered directly into the mains, or into elevated tanks or boilers, as is frequently the case for industrial purposes. With an available pressure of 10 lb. to the square inch a pressure filter 6 ft. in diameter will deal with about 8,400 gallons per hour.

These filters are in use at Dumbarton, Hereford, Lanark, Morley, Pontypridd, Rothesay, and other places.

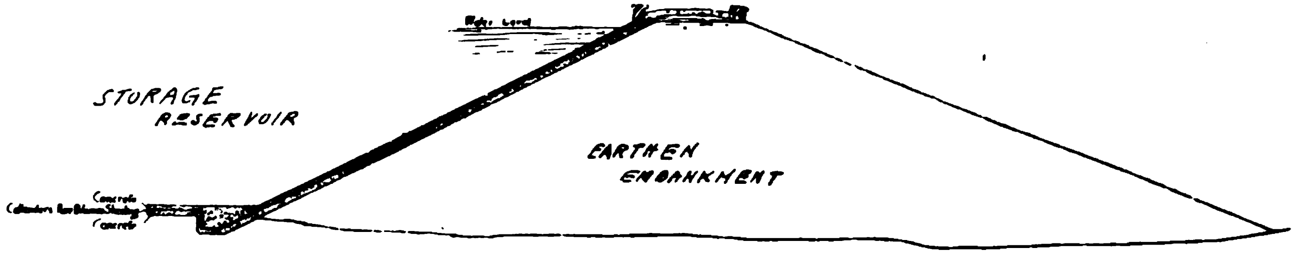
The illustration now given (Fig. 63) shows a battery of six "Hastings" polarite pressure filters for purifying one million gallons of water per day, which are contained within a building 65 ft. by 16 ft. wide. The filter is in the form of a cylinder either of cast iron, steel plates, or armoured concrete, and works under any pressure from 2 to 50 lb. to the square inch. The filtering material is "polarite," which consists of a black magnetic oxide of iron in a minutely porous and absorptive condition. It is supplied by the International Purification Syndicate of Westminster and is also in use in Southwold, Leighton Buzzard, Reading, South Africa, and many other places. The Hastings water supply is derived from the Ashdown Sand strata, and is heavily charged with iron, which gives the water before treatment a very decided discoloration. When inspecting these filters not long ago I was very much struck by the splendid purifying effect produced upon the water being passed through them; the appearance of the filtrate was certainly everything that could possibly be desired, and the Council's analyst pronounces it to be " of great organic purity and of the highest class." The speed of filtration is from 40,000 to 45,000 gallons per square yard per 24 hours, or about 1,770 gallons per hour. The mean rate of filtration in the ordinary London sand filters does not exceed 22 gallons per square yard per hour, so that it is readily seen that a mere fraction of the space required for the ordinary sand filter would suffice for polarite filters of the Hastings type.

Fig. 64 illustrates an apparatus made by Messrs. Hunter & English, London, for washing sand skimmed from the surfaces of sand filter beds, by employing the water pressure from the main to raise the sand from a hopper placed in the filter bed itself, and thence through a series of hoppers shown in the illustration, and back again into the filter bed. The number of hoppers shown in the plan and section are usually sufficient to wash about three cubic yards per hour with about 100 feet head of water in the supply main.

Other types of sand-washing apparatus are made by Messrs. J. Blakeborough & Son, J. Tylor & Sons (Walker's patent), Hardy & Padmore, of Worcester, and others.

A very general method of covering in service reservoirs until recent years has been that of forming brick arches supported by lines of brick piers within the reservoir. This practice is necessarily a costly one, and the effective capacity of the reservoir is much reduced by so many large supporting columns. A greatly improved method now

FIG. 65.—BITUMEN SHEETING IN OPEN STORAGE RESERVOIRS.



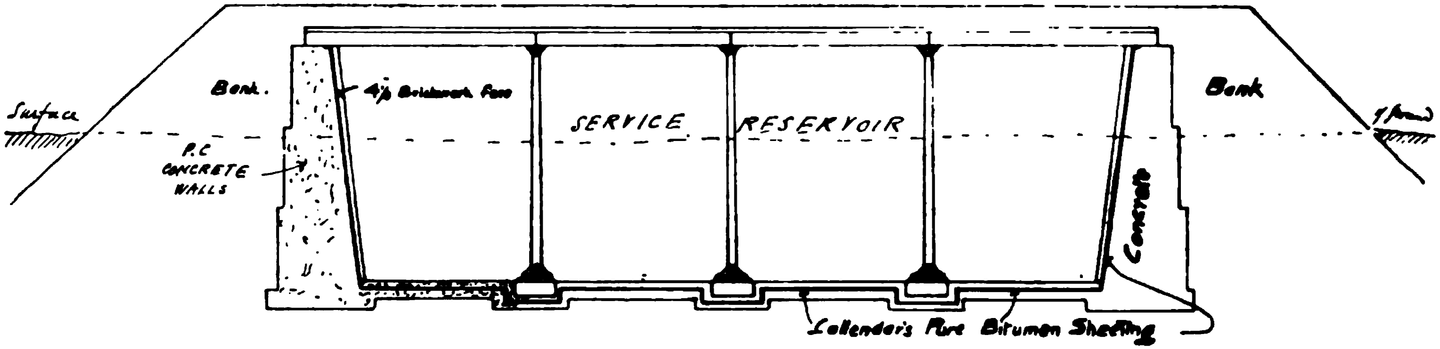


FIG. 66.—BITUMEN SHEETING IN COVERED SERVICE RESERVOIRS.

largely adopted is the use of a light design of concrete roof strengthened with expanded steel, and supported by steel joists and arched channel ribs, resting on steel stanchions. Many successful works of this description have been carried out in this country, amongst which may be named the new reservoirs of the Ipswich waterworks, and of the Hoylake and West Kirby waterworks, executed by the New Expanded Metal Co., of London and West Hartlepool.

Another feature in service reservoir construction is the growing use of bitumen sheeting for lining and rendering watertight the embankments of both open storage reservoirs and the walls of service reservoirs. The Figs. (65 and 66) illustrate its application to cases of this kind. In the open storage reservoirs the inner slopes of the embankments and the floor are lined with concrete, so as to form an even surface for the bitumen sheeting, which is then covered by an overlying layer of about 3 in. of concrete as a protection from mechanical damage. The slipping of this concrete is prevented by the formation of a concrete toe at the foot of the slope, in the manner shown in the figure. In the covered-service reservoir the sheeting is applied to the concrete walls of the reservoir, and is supported by an inner lining of 4½ in. brickwork, whilst that covering the bottom of the reservoir, which is continuous with the sheeting lining the walls, is protected by a 3-in. layer of concrete, or by brick paving, as may be necessary. Callender's bitumen sheeting, made of pure Trinidad bitumen, is very largely used for this class of work.

Conclusion

THERE are doubtless many matters of importance to which no reference has been made in the course of the present Lectures, and also numerous useful productions of the British manufacturer which have not found mention within these pages. This, I fear, must necessarily be the case, owing partly to the extent of the field to be covered, and partly to the great variety and number of the productions above named; but this, I think, only goes to show how vigorous is the activity of the many workers in this important sphere and how great is the progress to be recorded from year to year. It is hoped, however, that something of what may be thus lacking in fullness of detail may be compensated for by the addition, as an Appendix, to these lectures of classified "Lists of Manufacturers" in the various branches of municipal work, thus readily indicating the several quarters in which full inquiries may be made by those having proposals or schemes of new works under consideration or in contemplation.

In reviewing the progress that has taken place in the several branches of work dealt with, and in our comparison and contrast of present-day methods with those which obtained half a century or more ago, we are somewhat naturally led to make some sort of mental forecast as to possible future developments in this connexion. One strong distinctive feature between the conditions of then and now is the present all-pervading municipal system, which more or less influences the daily life of almost every inhabitant of these islands. It behoves the directors of municipal action, therefore, to take a wide view of their responsibilities, remembering that whilst their decisions are primarily of a local interest only, yet the united actions of the municipalities of this country must, in the aggregate, have their influence, be it great or small, upon the national prosperity of this country as a whole.

As I have already foreshadowed, progress in science and the social condition of the people has been the main factor in bringing about these modern-day changes. The hygienic, bacteriological, chemical, mechanical, and electrical sciences have taught us many and great things in the past, but who can venture to speculate upon, or to suggest a limit to, their possibilities in the future? They have shown us, amongst other things, reasons which we have long tested and verified by experience, for demanding pure water, unadulterated food, pure air, and cleanly surroundings, and have also shown us much towards the prevention and methods of communication of disease and the means of isolation and destruction of the pathogenic microbe. The dissemination and increase of such knowledge has been due, in no small degree, to the educational functions performed by the various medical, engineering, sanitary, and other scientific Institutions which we possess, and also to the commendable activity of the technical press. There is, however, no limit to this onward march of progress, and there will doubtless ever be much scope for future workers in the amelioration of the many evils attendant upon the continued concentration of population. Such advances as have been recorded in the past can only be regarded as an earnest of those to come, and every true discovery but widens the horizon for those labourers yet to enter the field.

APPENDIX TO LECTURE III

CLASSIFIED LIST OF BRITISH MANUFACTURERS INTERESTED IN WATER SUPPLY ENGINEERING

AIR COMPRESSORS.

Alley & MacLellan, Ltd.	Sentinel Works, Glasgow.
Arrol, Sir W., & Co., Ltd.	Dalmarnock Ironworks, Glasgow.
Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Beliss & Morcom, Ltd.	Ledsam Street, Birmingham.
Brotherhood, P.	Belvedere Road, S.E.
Braithwaite, Isaac, & Son,	Kendal.
Campbell Gas Engine Co., Ltd.	Halifax.
Cole, Marchent, & Morley, Ltd.	Prospect Foundry, Bradford.
Coles, H. J.,	London Crane Works, Derby.
Consolidated Pneumatic Tool Co., Ltd.	Palace Chambers, Westminster, S.W.
Craig, A. F. H., Ltd.	Paisley, N.B.
Davey, Paxman & Co., Ltd.	Colchester.
Daw, A. & Z.	11, Queen Victoria-street, E.C.
De Bergue & Co., Ltd.	Manchester.
Easton & Co., Ltd.	Broad Sanctuary Chambers, S.W.
Ellison, W. T., & Co., Ltd.	Irlams-o'-th'-Height.
Fawcett, Preston & Co., Ltd.	Liverpool.
Goodfellow, B., Ltd.	Hyde near Manchester.
Hathorn, Davey & Co.	Sun Foundry, Leeds.
Henderson, J. M., and Co.	King Street Works, Aberdeen.
Hughes & Lancaster	47, Victoria Street, S.W.
Jenkins, W. J., & Co., Ltd.	Retford.
Jessop & Appleby, Bros., Ltd.	Leicester.
Lacy-Hulbert, & Co.	25, Victoria Street, S.W.
Larmuth, Thomas & Co.	Todleben Iron Works, Salford, Manchester.
Leeds Engineering and Hydraulic Co.	Providence Works, Leeds.
Manlove, Alliott & Co., Ltd.	Nottingham.
Marryat & Place	28, Hatton Garden, E.C.

Meldrum Bros., Ltd.	Timperley, Manchester.
Newton, Bean & Mitchell	Dudley Hill, Bradford.
Parsons, C. A., & Co.	Heaton Wks., Newcastle-on-Tyne.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Premier Gas Engine Co., Ltd.	Sandiacre, near Nottingham.
Pulsometer Engineering Co., Ltd.	63, Queen Victoria Street, E.C.
Reader, E., & Sons	Phœnix Works, Nottingham.
Reavell & Co., Ltd.	Ipswich.
Richards, G., & Co., Ltd.	Broadheath, near Manchester.
Schram, Harker & Co.	Cannon Street House, E.C.
Scott, G., & Son, Ltd.	44, Christian Street, E.
Siebe, Gorman & Co.	Westminster Bridge Road, S.E.
Thwaites Bros., Ltd.	Bradford.
Tilghman's Patent Sand Blast Co., Ltd.	Broadheath, near Manchester.
Vauxhall Ironworks, Ltd.	Wandsworth Road, S.W.
Walker Brothers,	Pagefield Works, Wigan.
Westinghouse Brake Co., Ltd.	York Road, King's Cross, N.

Air Pumps.

Belliss & Morcom, Ltd.	Ledsam Street Works, Birmingham.
Cameron, A. S.	Steam Pump Works, Leadenhall Buildings, Leadenhall St., E.C.
Edwards' Air Pump Syndicate, Ltd.	3 and 5, Crown Court, Old Broad Street, E.C.
Weir, G. & J., Ltd.	Cathcart, Glasgow.

Boilers.

Abbot & Co., Ltd.	Park Works, Gateshead-on-Tyne.
Abbott & Co. (Newark), Ltd.	Newark-on-Trent.
Adamson, Daniel, & Co.	Dukinfield, Manchester.
Alley & Maclellan	Sentinel Works, Glasgow.
Anderton & Sons	Antley Boiler Works, Accrington.
Bellamy John, Ltd.	Millwall, E.
Belliss & Morcam, Ltd.	Ledsam Street, Brimingham.
Bodley Brothers & Co.	Exeter.
Burnet, L., & Co.	Govan, Glasgow.
Burrell C., & Sons, Ltd.	Thetford.
Campbell & Calderwood	Soho Engine Works, Paisley.
Central Marine Engine Works	West Hartlepool.
Chaplin, Alex., & Co.	Govan, Glasgow.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Clayton, Son, & Co., Ltd..	Leeds City Boiler Works, Leeds.

Clayton & Shuttleworth, Ltd.	Lincoln.
Coates, Victor, & Co., Ltd.	Belfast.
Cochran & Co., Annan, Ltd.	Annan, N.B.
Cradley Boiler Co.	Cradley Heath, Staffordshire.
Craig, A. F., & Co., Ltd.	Paisley, N.B.
Dalglish, A. & W.	West of Scotland Boiler Works, Pollokshaws, Glasgow.
Davey, Paxman & Co., Ltd.	Colchester.
Day, Summers & Co., Ltd.	Northam Ironworks, Southampton.
Dodman, Alfred, Ltd.	Highgate Works, King's Lynn.
Easton & Co., Ltd.	Erith Iron Works, Erith, Kent.
Easton & Bessemer, Ltd.	Taunton.
Evans D. Llewellin	120, Bute Street, Cardiff.
Farrer, A.	Newark-on-Trent.
Fawcett, Preston & Co., Ltd.	Liverpool.
Fleming & Ferguson, Ltd.	Paisley, Scotland.
Foster, W., & Co., Ltd.	Lincoln.
Fowler, J., & Co. (Leeds), Ltd.	Leeds.
Fraser & Chalmers, Ltd.	43, Threadneedle Street, E.C.
Galloways Limited	Manchester.
Grantham Crank and Iron Co., Ltd.	Grantham.
Garratt, R., & Sons	Leiston Works, Suffolk.
Gimson & Co., Ltd.	Leicester.
Green, Thomas & Son, Ltd.	Smithfield Ironworks, Leeds; and New Surrey Works, Southwark Street, S.E.
Hanna, Donald & Wilson	Paisley, N.B.
Hartley & Sudgen, Ltd.	Halifax.
Hawthorn R. & W., Leslie & Co., Ltd.	Newcastle-on-Tyne.
Hayes, Edward	Stony Stratford, Wolverton.
Hindley, E. S., & Sons	11, Queen Victoria Street, E.C.
Hornsby, R., & Sons, Ltd.	Grantham.
Isca Foundry and Engineering Co.	Newport, Mon.
Jessop & Appleby Brothers, (Leicester and London), Ltd.	Leicester and London.
Kincaid, John G., & Co.	Greenock, Scotland.
Lees, T. & R.	Hollinwood, near Manchester.
Low Moor Iron Works	Bradford, Yorkshire.
Manlove, Alliott & Co., Ltd.	Nottingham.
Marshall, Sons & Co., Ltd.	Gainsborough.
McKie & Baxter	Copland Works, Govan, Glasgow.

Mirrles, Watson & Co., Ltd. . .	Scotland Street, Glasgow.
Mordey, Carney (Southampton), Ltd.	Woolston Works, Southampton.
Mumford, A. G.	Culver St. Ironworks, Colchester.
Napier Brothers, Ltd. . . .	100, Hyde Park Street, Glasgow.
Norman, John	131A, St. Vincent Street, Glasgow.
Olrick, L., & Co.	Palmerston House, Bishopsgate Street, E.C.
Parsons Marine Steam Turbine Co., Ltd.	Turbinia Works, Wallsend-on-Tyne.
Penman & Co..	Strathclyde Street, Glasgow.
Piggott, Thomas, & Co., Ltd.. .	Springhill, Birmingham.
Plenty & Son, Ltd.	Eagle Ironworks, Newbury, Berks.
Ransomes, Sims & Jefferies, Ltd.	Ipswich.
Richardsons, Westgarth & Co., Ltd.	West Hartlepool.
Robey & Co., Ltd.	Lincoln.
Rose, Downs & Thompson, Ltd. .	Hull.
Ross & Duncan	Glasgow.
Rowland, B. R., & Co., Ltd. . .	Climax Works, Reddish, near Stockport.
Royal Dutch Forge Co. . . .	Leiden, Holland.
Russell George, & Co., Ltd. . .	Motherwell, near Glasgow.
Ruston, Proctor & Co., Ltd. . .	Sheaf Ironworks, Lincoln.
Simpson, Strickland & Co., Ltd.	Dartmouth.
Sinclair, G.	Albion Boiler Works, Leith, N.B.
Smedley Brothers, Ltd. . . .	Belper.
Smith, A. & W., & Co., Ltd. . .	Eglinton Engine Works, Glasgow.
Smokeless Chimney Co., Ltd. . .	Albert Square, Manchester.
Smulders, A. F.	Rotterdam.
Spencer, W. H., & Co.	Hitchin, Hertfordshire.
Stirling Boiler Co., Ltd. . . .	2, St. Andrew Square, Edinburgh.
Tangyes Ltd.	Cornwall Works, Birmingham.
Tannett, Walker, & Co., Ltd. . .	Hunslet, Leeds.
Thornycroft, J. I., & Co., Ltd. .	Chiswick, W.
Tinker, Shenton & Co., Ltd. . .	Hyde, near Manchester.
Toward, T., &. Co.	9, St. Lawrence, Newcastle-on-Tyne.
Turner, E. R. & F., Ltd. . . .	Ipswich.
Vauxhall Iron Works Co., Ltd. .	Wandsworth Road, S.W.
Vosper & Co., Ltd.	Portsmouth.
Yarrow & Co., Ltd.	Poplar, E.

BOILERS (WATER-TUBE).

Abbott & Co., Ltd.	Newark-on-Trent.
Babcock & Wilcox, Ltd. . . .	30, Farringdon Street, E.C.

Consolidated Engineering Co., Ltd.	Slough, Buckinghamshire.
Davey, Paxman & Co., Ltd.	Colchester.
Fleming & Ferguson, Ltd.	Paisley, N.B.
Hornsby, R., & Sons, Ltd.	Grantham.
Mumford, A. G.,	Culver Street Works, Colchester.
Rowland, B. R., & Co., Ltd.	Climax Works, Reddish, near Stockport.
Simpson, Strickland & Co., Ltd.	Dartmouth.
Stirling Boiler Co., Ltd.	2, St. Andrew Square, Edinburgh.
Stirling Co. (British Branch)	53, Deansgate Arcade, Manchester.
Thornycroft, J. I., & Co., Ltd.	Chiswick.
Willans & Robinson, Ltd.	Rugby.
Yarrow & Co., Ltd.	Poplar, E.

BOILER COMPOSITION.

Bell's Asbestos Co., Ltd.	59½, Southwark Street, S.E.
Litholine Co.,	11, Blackfriars Street, Manchester.
Stern Brothers,	57, Gracechurch Street, E.C.
United Asbestos Co., Ltd.	Dock House, Billiter Street, E.C.
Witty & Wyatt, Ltd.	88, Leadenhall Street, E.C.

BOILER COVERING.

Bell's Asbestos Co., Ltd.	59½, Southwark Street, S.E.
Cresswell's Asbestos Co., Ltd.	Wellington Mills, Bradford.
Kenyon, W., & Sons	Dukinfield, Manchester.
Leroy, F., & Co.	Gray Street, Commercial Road, E.
Toope's Asbestos Covering Co., Ltd.	Stepney-square, E.
United Asbestos Co., Ltd.	Dock House, Billiter Street, E.C.
Witty & Wyatt, Ltd.	88, Leadenhall Street, E.C.

BOREWELLS.

Batchelor, R. D.,	73, Queen Victoria Street, E.C.
Duke & Ockenden,	126, Southwark Street, S.E.
Hamblet, J.	Eagle Foundry, West Bromwich.
Isler, C., & Co.	Bear Lane, Southwark, S.E.
Le Grand & Sutcliff	125, Bunhill Row, E.C.
Mather & Platt, Ltd.	Salford Ironworks, Manchester
Richards, R., & Co.	Upper Ground Street, S.E.
Thom, John C.	Canal Works, Patricroft, England.

CENTRIFUGAL PUMPS.

Allen, W. H., Son & Co., Ltd.	Queen's Engineering Works, Bedford.

APPENDIX TO LECTURE III

Bailey, W. H., & Co., Ltd.	Salford, Manchester.
Campbell & Calderwood	Soho Engine Works, Paisley.
Cherry, John, & Sons	Pump Works, Beverley, Yorkshire.
Drysdale & Co.	Bon Accord Engine Works, Glasgow.
Gunther, W., & Sons	Central Works, Oldham.
Gywnne Limited.	Brooke Street Works, E.C.
Gwynne, J. & H., Ltd.	81, Cannon Street, E.C.
Hathorn, Davey & Co., Ltd.	Leeds.
Heenan & Froude, Ltd.	Manchester.
Marshall, Sons & Co., Ltd.	Gainsborough.
Owens, S., & Co.	Whitefriars Street, E.C.
Pulsometer Engineering Co., Ltd.	Nine Elms Ironworks, Reading.

CONDENSERS.

Allen, W. H., Son, & Co., Ltd.	Bedford.
Belliss & Morcom, Ltd.	Birmingham.
Boby, William	Salisbury House, London Wall, E.C.
Caird & Rayner	777, Commercial Road, E.
Campbell & Calderwood	Soho Engine Works, Paisley.
Carruthers, J. H., & Co.	Polmadie Works, Glasgow.
Cole, Marchent & Morley	Bradford.
Craig, A. F., & Co., Ltd.	Paisley.
Davey, Paxman & Co., Ltd.	Colchester.
Dodman, A., Ltd.	King's Lynn.
Easton & Co.	Broad Sanctuary Chambers, S.W.
Edwards Air Pump Syndicate	3, Crown Court, E.C.
Ellison, W. T., & Co., Ltd.	Irlams-o'-th'-Height, Manchester.
Fairbairn, Lawson, Combe, Barbour, Ltd.	52, Lime Street, E.C.
Fawcett, Preston & Co., Ltd.	Liverpool.
Foster, W., & Co., Ltd.	Wellington Foundry, Lincoln.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, E.C.
Green, Thomas, & Son, Ltd.	Smithfield Ironworks, Leeds; and New Surrey Works, Southwark Street, S.E.
Hudson Economiser Co. Ltd.	7, Victoria Street, S.W.
Kirkaldy, J., Ltd.	101, Leadendhall Street, E.C.
Klein Engineering Co., Ltd.	94, Market Street, Manchester.
Ledward & Beckett, Ltd.	Sanctuary House, Tothill Street, Westminster, S.W.
Mather & Platt	Manchester.
Mirrlees, Watson & Co., Ltd.	Scotland Street, Glasgow.

Normandy's Fresh Water Co., Ltd.	Victoria Dock Road, E.
Piggott, Thomas, & Co., Ltd. . .	Springhill, Birmingham.
Pulsometer Engineering Co., Ltd.	Nine Elms Ironworks, Reading.
Reader, E., & Sons	Phœnix Works, Nottingham.
Royles Limited	Irlam, near Manchester.
Scott, Ernest, & Mountain, Ltd. .	Close Works, Newcastle-on-Tyne.
Storey, I., & Sons, Ltd. . . .	Empress Foundry, Manchester.
Tannett, Walker, & Co. . . .	Hunslet, Leeds.
Vauxhall Ironworks Co. . . .	Wandsworth Road, S.W.
Weir, G. & J., Ltd.	Cathcart, Glasgow.

ECONOMISERS

Clay Cross Co.	Clay Cross, near Chesterfield.
Green, E., & Son	2, Exchange Street, Manchester.
Hudson Economiser Co., Ltd. .	7, Victoria Street, S.W.
Lowcock, A., Ltd.	Coleham Foundry, Shrewsbury.
Mechan & Sons	Scotstoun Ironworks, Glasgow.
Meldrum Brothers, Ltd. . . .	Timperley, near Manchester.
Roberts Brothers	Dukinfield, Manchester.
Smokeless Chimney Co., Ltd. . .	Albert Square, Manchester.

ENGINE AND BOILER FITTINGS.

Bailey, W. H., & Co., Ltd. . . .	Albion Works, Salford, Manchester.
Bell's Asbestos Co., Ltd. . . .	Southwark Street, S.E.
Drake & Gorham, Ltd. . . .	66, Victoria Street, S.W.
Empire Engineering Co. . . .	Failsworth, Manchester.
Galloways Ltd.	Knott Mill, Manchester.
Green & Boulding	105, Bunhill Row, E.C.
Hamilton, J. B., & Co. . . .	145, Cannon Street, E.C.
Hayward-Tyler & Co. . . .	90, Whitecross Street, E.C.
Holden & Brooke, Ltd. . . .	Sirius Works, West Gorton, Manchester.
Hopkinson, J., & Co., Ltd. . .	Huddersfield.
Hulburd Engineering Co. . . .	150, Leadenhall Street, E.C.
Lowmoor Co., Ltd.	Lowmoor Ironworks, Bradford.
McNeil, C., jun.	Kinning Park Ironworks, Glasgow.
Midland Manufacturing Co., Ltd.	20, Change Alley, Sheffield.
Newman, Hender & Co., Ltd. . .	Woodchester, near Stroud, Gloucestershire.
Noakes, T., & Son	35, Brick Lane, E.

APPENDIX TO LECTURE III

Piercy & Co.	Broad Street Engine Works, Birmingham.
Piggott, T., & Co.	Birmingham.
Rimington Brothers	Carlisle.
Russell, John, & Co., Ltd.	Alma Works, Walsall.
Scott, Ernest, & Mountain	Close Works, Newcastle-on-Tyne.
Smith, S., & Sons	Basford Brass Works, Nottingham.
Stewarts & Lloyds, Ltd.	Birmingham.
Storey, I., & Sons, Ltd.	Knott Mill, Manchester.
Turnbull, A., & Co., Ltd.	Bishopbriggs, Glasgow.
Weir, G. & J., Ltd.	Cathcart, Glasgow.

ENGINES (FOR PUMPING).

Abbot, John, & Co., Ltd.	Gateshead-on-Tyne.
Adamson, Daniel, & Co.	Dukinfield, Manchester.
Andrew Barclay, Sons, & Co., Ltd.	Kilmarnock, N.B.
Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Belliss & Morcom, Ltd.	Ledsam St. Works, Birmingham.
Berry, Henry, & Co., Ltd.	Croydon Works, Leeds.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Coates, Victor, & Co., Ltd.	Belfast.
Davey, Henry	3, Princes Street, Westminster, S.W.
Davey, Paxman & Co., Ltd.	Colchester.
Easton & Co.	Erith, Kent.
Fairbairn, Lawson, Combe, Barbour, Ltd.	Engine Builders, Belfast
Fielding & Platt, Ltd.	Gloucester.
Fleming and Ferguson, Ltd.	Paisley, N.B.
Fraser & Chalmers, Ltd.	43, Threadneedle Street, E.C.
Fullerton, Hodgart and Barclay, Ltd.	Vulcan Foundry and Engine Works, Paisley.
Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Gwynne & Co.	Brooke Street Works, Holborn. E.C.
Hayward-Tyler, & Co.	90, Whitecross Street, E.C
Hathorn, Davey & Co., Ltd.	Leeds.
Jessop & Appleby Brothers (Leicester and London), Ltd.	Leicester and London.
Leeds Engineering and Hydraulic Co., Ltd.	Providence Works, Cross Stamford Street, Leeds.
McOnie, A., & P. W.	Govan, Glasgow.

Moreland, R., & Son, Ltd.	25 and 27, Old Street, E.C.
Musgrave Brothers	Crown Point Foundry.
Pulsometer Engineering Co. Ltd.	Nine Elms Ironworks, Reading.
Rice & Co. (Leeds), Ltd.	Neville Works, Elland Road, Leeds.
Robey & Co., Ltd.	Lincoln.
Sandycroft Foundry Co., Ltd.	Near Chester.
Smith, Hugh, & Co.	Glasgow.
Simpson, J., & Co.	Engines, Plimlico, S.W.
Tangyes Limited	Cornwall Works, Birmingham.
Tannett, Walker & Co., Ltd.	Leeds.

Gas and Oil Engines.

Gas Engines.

Andrew, J. E. H., Ltd.	Reddish, near Stockport.
Blackstone & Co., Ltd.	Stamford.
British Westinghouse Electric Co., Ltd.	Norfolk Street, Strand, W.C.
Campbell Gas Engine Co., Ltd.	Halifax.
Clayton & Shuttleworth, Ltd.	Lincoln.
Crossley Brothers, Ltd.	Openshaw, Manchester.
Cundall, R., & Sons, Ltd.	Shipley, Yorkshire.
Dick, Kerr & Co., Ltd.	110, Cannon Street, E.C.
Dudbridge Ironworks, Ltd.	Stroud, Gloucestershire.
Fielding and Platt, Ltd.	Gloucester.
Gardner, L., & Sons, Ltd.	Patricroft, Manchester.
Griffin Engineering Co.	Bath.
Kynoch Limited	Witton, Birmingham.
Mather & Platt, Ltd.	Salford Ironworks, Manchester.
National Gas Engine Co., Ltd.	Ashton-under-Lyne.
Newton Electrical Works, Ltd.	Taunton.
Pollock, Whyte & Waddel	Johnstone, N.B.
Premier Gas Engine Co. Ltd.	Sandiacre, Nottingham.
Robey and Co., Ltd.	Lincoln.
Tangyes Limited	Birmingham.

Oil Engines.

Blackstone and Co., Ltd.	Stamford.
Britannia Co.	Colchester.
Campbell Gas Engine Co. Ltd.	Halifax.
Clayton & Shuttleworth, Ltd.	Lincoln.
Crossley Brothers, Ltd.	Openshaw, Manchester.
Cundall, R. & Sons	Shipley, Yorkshire.
Davies, George, & Co.	Abergavenny.
Donkin, B., & Clench, Ltd.	Chesterfield.

Dudbridge Ironworks, Ltd.	Stroud, Gloucestershire.
Gardner, L., & Sons, Ltd.	Patricroft, Manchester.
Griffin Engineering Co.	Bath.
Gwynne, J. & H., Ltd.	81, Cannon Street, E.C.
Hornsby & Sons, Ltd.	Grantham.
National Gas Engine Co., Ltd.	Wellington Works, Ashton-under-Lyne.
Newton Electrical Works, Ltd.	Taunton.
Pollock, Whyte & Waddel	Johnstone, N.B.
Priestman Brothers, Ltd.	Hull.
Robey & Co., Ltd.	Lincoln.
Ruston, Proctor & Co., Ltd.	Lincoln.
Samuelson & Co., Ltd.	Banbury, Oxon.
Tangyes Limited	Birmingham.
Vosper & Co., Ltd.	Broad Street, Portsmouth.

HEATERS FOR FEED WATER.

Babcock & Wilcox, Ltd.	30, Farringdon Street, E.C.
Baker's Patent Appliances Co., Ltd.	Melrose St. Works, Scarborough.
Boby, William	Salisbury House, London Wall, E.C.
Burnet, L., & Co.	Govan, Glasgow.
Caird & Rayner	777, Commercial Road, E.
Clay Cross Co.	Chesterfield.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Easton & Co., Ltd.	Broad Sanctuary Chambers, S.W.
Erith's Engineering Co.	70, Gracechurch Street, E.C.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, E.C.
Holden & Brooke, Ltd.	Sirius Works, West Gorton, Manchester.
Hudson Economiser Co., Ltd.	7, Victoria Street, S.W.
Kirkaldy, John, Ltd.	101, Leadenhall Street, E.C.
Liverpool Engineering and Condenser Co., Ltd.	Brunswick Dock, Liverpool.
Lowcock, A., Ltd.	Coleham Foundry, Shrewsbury.
Maxim, Sir Hiram, Electrical and Engineering Co., Ltd.	65, 66, 67, Gracechurch Street, E.C.
Meldrum Brothers, Ltd.	Timperley, near Manchester.
Normandy's Patent Marine Aerated Fresh Water Co., Ltd.	Victoria Dock Road, E.
Richardsons. Westgarth & Co., Ltd.	Hartlepool.
Royles Limited	Irlam, near Manchester.
Shore, T., & Sons	Albion Foundry, Hanley.

Simpson, James, & Co., Ltd.	101, Grosvenor Road, S.W.
Tangyes Limited	Birmingham.
Weir, G. & J., Ltd.	Cathcart, Glasgow.
Wright, Joseph, & Co.	Tipton, Staffordshire.

Hydraulic Machinery.

Abbot, John, & Co., Ltd.	Park Works, Gateshead-on-Tyne.
Arrol, Sir William & Co., Ltd	Dalmarnock Ironworks, Bridgeton, Glasgow.
Bailey, W. H. & Co., Ltd.	Albion Works, Salford, Manchester.
Belliss & Morcom, Ltd.	Birmingham.
Berry, Henry & Co., Ltd.	Croydon Works, Leeds.
Coles, H. J.	London Crane Works, Derby.
Cowans, Sheldon & Co., Ltd.	Carlisle.
Craig, A. F., & Co., Ltd.	Paisley, N.B.
Crow, Harvey & Co.	Park Grove Ironworks, Glasgow.
Drysdale & Co.	Bon Accord England Works, Glasgow.
Davis & Primrose	Leith, N.B.
De Bergue & Co., Ltd.	Manchester.
Dudbridge Iron Works	Stroud, Gloucestershire.
Easton & Bessemer, Ltd.	Taunton.
Easton & Co.	Erith, Kent.
East Ferry Road Engineering Works Co., Ltd.	Millwall, E.
Fawcett, Preston & Co.	Liverpool.
Fielding & Platt, Ltd. (Tweddell's System)	Gloucester.
Fullerton, Hodgart and Barclay, Ltd.	Vulcan Foundry and Engine Works, Paisley.
Galloways, Limited	Manchester.
Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Greenwood & Batley, Ltd.	Leeds.
Gwynne & Co.	Brooke Street Works, Holborn, E.C.
Hathorn, Davey & Co., Ltd.	Leeds.
Hayward-Tyler & Co.	90, Whitecross Street, E.C.
Hunter & English	Bow, E.
Leeds Engineering and Hydraulic Co., Ltd.	Providence Works, Cross Stamford Street, Leeds.
McOnie, A. & P. W.	Govan, Glasgow.
Marshall, Fleming & Jack	Motherwell, N.B.
Middleton, Robert	Sheepscar Foundry, Leeds.

Musgrave Bothers	Crown Point Foundry, Leeds.
Musker, C. & A., Ltd.	Liverpool.
Owens, S., & Co.	Whitefriars Street, E.C.
Pulsometer Engineering Co., Ltd.	Nine Elms Ironworks, Reading.
Rice & Co. (Leeds), Ltd.	Neville Works, Elland Road, Leeds.
Rose, Down & Thompson, Ltd.	Old Foundry, Hull.
Simpson, J., & Co.	Pimlico, S.W.
Smith, A., & Stevens	Queen's Road, Battersea.
Smith Brothers & Co.	Kingston Engine Works, Glasgow.
Smith, Hugh, & Co.	Glasgow.
Stewart, D., & Co.	London Road, Ironworks, Glasgow.
Tangyes Limited	Cornwall Works, Birmingham.
Tannett, Walker & Co.	Leeds.
Waygood & Otis, Ltd.	Falmouth Road, E.C.
West Hydraulic Engineering Co.	23, College Hill, E.C.
Wilson, J., & Son	Vulcan Works, Johnstone, N.B.
Youngs	Ryland Street Works, Birmingham

Hydraulic Rams.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Blake, John, Ltd.	Oxford Street Works, Accrington. Lancashire.
Owens, S., & Co.	Whitefriars Street, E.C.

Indicators.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Hannan & Buchanan	75, Robertson Street, Glasgow.
Schäffer & Budenberg, Ltd.	Whitworth Street, London Road, Manchester.
Smith, Sydney, & Sons	Basford Brass Works, Nottingham.

Injectors.

Armstrong, James, & Co., Ltd.	116, Queen Victoria Street, E.C.
Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Consolidated Engineering Co., Ltd.	Slough.
Craig, A. F., & Co.	Paisley.
Davies & Metcalfe, Ltd.	4, St. Ann's Square, Manchester.
Empire Engineering Co.	Failsworth, Manchester.
Dempster, Moore & Co.	49, Robertson Street, Glasgow.

Gresham & Craven, Ltd. . . . Manchester.
Hayward-Tyler & Co. . . . . 90, Whitecross Street, E.C.
Holden & Brooke, Ltd. . . . Sirius Works, West Gorton, Manchester.
Klinger, Richard, & Co. . . . 66, Fenchurch Street, E.C.
Pulsometer Engineering Co., Ltd. 63, Queen Victoria Street, E.C.
Schäffer & Budenberg, Ltd. . . Whitworth Street, London Road, Manchester.
Smith, S., & Sons . . . . . Basford Brass Works, Nottingham.
Willcox, W. H. & Co., Ltd.. . 23, Southwark Street, S.E.

LUBRICANTS AND OILS.

Asbestos Co. Ltd. (The United) . Dock House, Billiter Street, E.C.
Barns W., & Son . . . . . Perforating Works, Chalton Street, N.W.
Bell's Asbestos Co., Ltd. . . . 59½, Southwark Street, S.E.
Blumann & Stern, Ltd. . . . Plough Bridge, Deptford, S.E.
Bremner, John A., & Co. . . . Albert Street, Manchester.
Duncan, Watson & Co. . . . Dashwood House, New Broad St., E.C.
Eley Brothers, Ltd. . . . . 254, Gray's Inn Road, W.C.
Hobdell, Way & Co., Ltd.. . . 63, Crutched Friars, E.C.
Laycock, W. S., Ltd. . . . . Victoria Street Works, Sheffield.
Meade, King, Robinson & Co. . . 11, Old Hall Street, Liverpool.
Mica Lubricant Co.. . . . . . South Shields.
Palfreyman, W. H., & Co.. . . 17, Goree Piazzas, Liverpool.
Price's Patent Candle Co., Ltd. . Battersea, S.W.
Price's Patent Candle Co., Ltd. . 3, Cross Street, Manchester.
Rimington Brothers . . . . Carlisle.
Snowdon, Sons & Co., Ltd. . . Millwall, E.
Stern Brothers . . . . . . 57, Gracechurch Street, E.C.
Trier Brothers . . . . . . 1, Great George Street, S.W.
Wakefield, C. C., & Co. . . . . 27, Cannon Street, E.C.
Wells, Henry, Oil Co. . . . . Imperial Oil Works, Deansgate. Manchester.
Willcox, M. H., & Co., Ltd. . . 23, Southwark Street, S.E.

LUBRICATORS.

Bailey, W. H., & Co., Ltd.. . . Albion Works, Salford, Manchester.
Bell's Asbestos Co., Ltd . . . . 59½, Southwark Street, S.E.
Butterworth Brothers, Ltd. . . Newton Heath Glass Works, Manchester.

Empire Engineering Co.	Failsworth, Manchester.
Guest, Keen & Nettlefolds, Ltd.	Birmingham.
Hulburd Engineering Co.	150, Leadenhall Street, E.C.
Hunt & Mitton	Oozells Street, North Birmingham.
Klinger, Richard, & Co.	66, Fenchurch Street, E.C.
Piggott, Thomas, & Co.	Springhill, Birmingham.
Reid, William, & Co.	112, Fenchurch Street, E.C.
Schäffer & Budenberg, Ltd.	Whitworth Street, London Road, Manchester.
Stern Brothers.	57, Gracechurch Street, E.C.
Tangyes Limited	Cornwall Works, Birmingham.
Trier Brothers	1, Gt. George Street, Westminster.
Vickers, Benjamin R., & Sons	Leeds.
Wakefield, C. C., & Co.	27, Cannon Street, E.C.
Willcox, W. H., & Co., Ltd.	23, Southwark Street, S.E.

Meters.

Beck & Co.	130, Gt. Suffolk Street, Southwark.
Glenfield & Kennedy	Kilmarnock.
Guest & Chrimes	Rotherham.
Ham, Baker, & Co.	13, Grosvenor Road, Westminster, S.W.
Kent, George	199–201, High Holborn, London.
Manchester Water Meter Co.	Ardwick, Manchester.
Palatine Engineering Co., Ltd.	10, Blackstock Street, Liverpool.
Tylor, J., & Sons, Ltd.	2, Newgate Street, E. C.

Pipes (Cast and Wrought Iron).

Abbot, J., & Co., Ltd.	Gateshead-on-Tyne.
Barrowfield Ironworks, Ltd.	Glasgow.
British Mannesmann Tube Co. Ltd.	Landore, R.S.O.
Clay Cross Co.	Chesterfield.
Haley, E. & W. H.	Thornton Road, Bradford.
Hemingways, Limited	Middlesbrough.
Isca Foundry Co.	Newport, Mon.
Laidlaw, R., & Son, Ltd.	Glasgow.
Mechan & Sons	Scotstoun Works, Glasgow.
Morton, F., & Co., Ltd.	Garston, Liverpool.
Piggott, T., & Co., Ltd.	Atlas Works, Birmingham.
Pulsometer Engineering Co. Ltd.	Reading.
Sheepbridge Coal & Iron Co.	Chesterfield.
Smith, Patterson & Co., Ltd.	Pioneer Foundry, Blaydon-on-Tyne.

Stewarts & Lloyds, Ltd.	Birmingham.
Stewarts & Lloyds, Ltd.	41, Oswald Street, Glasgow.
Staveley Coal and Iron Co. Ltd.	Near Chesterfield.
Universal Tube Co. Ltd.	Chesterfield.

PUMPS AND PUMPING MACHINERY.

Abbot, John, & Co., Ltd.	Park Works, Gateshead-on-Tyne.
Allen, William	70, Park Street, Manchester.
Allen, W. H., Son, & Co., Ltd.	Queen's Engineering Works Bedford.
Bailey, W. H. & Co.	Albion Works, Salford, Manchester.
Baker Blower Engineering Co.	Stanley Works, Sheffield.
Baker's Patent Appliances Co.,Ltd.	Scarborough.
Batchelor, R. D.	73, Queen Victoria Street, E.C.
Berry, Henry, & Co., Ltd.	Croydon Works, Leeds.
Bever, Dorling & Co., Ltd.	Union Foundry, Dewsbury.
Braithwaite, Isaac, & Son	Kendal.
British Thomson-Houston Co.	Rugby.
Cameron, John, Ltd.	Oldfield Road Ironworks, Salford.
Carruthers, J. H., & Co., Ltd.	Polmadie Ironworks, Glasgow.
Chaplin, Alex., & Co.	Govan, Glasgow.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Clay Cross Co.	Clay Cross, near Chesterfield.
Clayton & Shuttleworth, Ltd.	Lincoln.
Cochrane, John	Barrhead, N.B.
Coles, H. J.	London Crane Works, Derby.
Crow, Harvey & Co.	Park Grove Ironworks, Glasgow.
Davey, Henry	3, Princes Street, Westminster, S.W.
Davey, Paxman & Co., Ltd.	Colchester.
Dempster, Moore & Co, Ltd.	49, Robertson Street, Glasgow.
Drysdale & Co.	Bon Accord Engine Works, Glasgow.
East Ferry Road Engineering Works Co., Ltd.	Millwall, E.
Easton & Co., Ltd	Erith Ironworks, Erith, Kent.
Edward Air Pump Syndicate, Ltd.	3 and 5 Crown Court, Old Broad Street, E.C.
Ellison, W. T., & Co., Ltd.	Irlams-o'-th'-Height, Manchester.
Evans, Joseph, & Sons	Wolverhampton.
Fairbairn, Lawson, Combe, Barbour, Ltd.	52, Limehouse Street, E.C.
Fawcett, Preston & Co., Ltd.	Liverpool.
Fielding & Ferguson, Ltd.	Gloucester.

Fleming & Ferguson, Ltd.	Paisley, N.B.
Fraser & Chalmers, Ltd.	43, Threadneedle Street, E.C.
Fullerton, Hugart and Barclay, Ltd.	Vulcan Foundry and Engine Works, Paisley.
Galloways Limited.	Knott Hill, Manchester.
Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Greenwood & Batley, Ltd.	Leeds.
Gunther, W., & Sons	Oldham.
Gwynne & Co.	Brooke Street Works, Holborn, E.C.
Gwynne, J. & H., Ltd.	81, Cannon Street, E.C.
Hanna, Donald & Wilson	Paisley.
Hartnell, W., & Co., Ltd.	Volt Works, Leeds.
Hathorn, Davey & Co., Ltd.	Leeds.
Hayward-Tyler & Co.	90 and 92, Whitecross Street, E.C.
Holden & Brooke, Ltd.	Sirius Works, West Gorton, Manchester.
Hornsby, R., & Sons, Ltd.	Grantham.
Hughes & Lancaster	47, Victoria Street, Westminster, S.W.
Hunter & English	Bow, E.
Isca Foundry & Engineering Co.	Newport, Mon.
Isler, C., & Co.	Artesian Works, Bear Lane, S.E.
Jessop & Appleby Brothers (Leicester and London), Ltd.	Leicester and London.
Kirkaldy, J., Ltd.	101, Leadenhall Street, E.C.
Lacy-Hulbert & Co.	25, Victoria Street, S.W.
Lancaster & Tonge, Ltd.	Pendleton, near Manchester.
Leeds Engineering and Hydraulic Co., Ltd.	Providence Works, Cross Stamford Street, Leeds.
Lobnitz & Co., Ltd.	Renfrew, Scotland.
Lund, E.	Park Ironworks, Stockport.
Mather & Platt	Manchester.
Moreland, Richard, & Son, Ltd.	25 and 27, Old Street, E.C.
Mumford, A. G.	Culver Street Ironworks, Colchester.
Musgrave Brothers	Crown Point Foundry, Leeds.
Musker, C. & A., Ltd.	Liverpool.
Newton, Bean & Mitchell	Dudley Hill, Bradford.
Owens, S., & Co.	Whitefriars Street, E.C.
Parsons, C. A., & Co.	Heaton Works, Newcastle-on-Tyne.
Pearn, Frank, & Co., Ltd.	Manchester.
Perry, T., & Sons	Bilston, Staffordshire.
Picking, Hopkins & Co.	Arnold Works, Bow, E.

Ransomes & Rapier, Ltd.	Waterside Ironworks, Ipswich.
Reader, E., & Sons, Ltd.	Nottingham.
Richardson, A. W.	Skew Bridge Works, Patricroft, near Manchester.
Shore, T., & Sons	Albion Foundry, Manley.
Stothert & Pitt, Ltd.	Bath.
West Hydraulic Engineering Co.	23, College Hill, E.C.
Westinghouse Brake Co., Ltd.	York Road, King's Cross, N.

STEAM ENGINES.

Adamson, D., & Co.	Dukinfield, Manchester.
Allen, W.	70, Port Street, Manchester.
Bennis, E., & Co., Ltd.	Bolton.
Blackstone & Co., Ltd.	Stamford.
Booth, J., & Brothers	Rodley, near Leeds.
Brazil, Holborow & Straker, Ltd.	Vulcan Works, Bristol.
Brotherhood, P.	Belvedere Road, S.E.
Buckley & Taylor, Ltd.	Castle Works, Oldham.
Bumsted & Chandler	Hednesford, Staffordshire.
Burrell, C., & Sons, Ltd.	Thetford, Norfolk.
Central Marine Engine Works	West Hartlepool.
Chaplin, A., & Co.	Govan, Glasgow.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Coates, Victor & Co., Ltd.	Belfast.
Cole, Marchent & Morley, Ltd.	Prospect Foundry, Bradford.
Coles, H. J.	London Crane Works, Derby.
Coltman, H., & Sons	Loughborough.
Consolidated Engineering Co., Ltd.	Slough.
Crow, Harvey & Co.	Park Grove Ironworks, Glasgow.
Davey, Henry,	3, Princes Street, S.W.
Dempster, Moore & Co.	49, Robertson Street, Glasgow.
Dodman, A., Ltd.	King's Lynn.
Donkin, B., & Clench, Ltd.	Chesterfield.
Easton & Bessemer, Ltd.	Taunton.
Fawcett, Preston & Co., Ltd.	Liverpool.
Ferranti Limited	Hollinwood, Lancashire.
Foster, W., & Co., Ltd.	Wellington Foundry, Lincoln.
Fowler, J., & Co. (Leeds), Ltd.	Leeds.
Fraser & Chalmers, Ltd.	43, Threadneedle Street, E.C.
Garrett, R., & Sons	Leiston, Suffolk.
Gimson & Co., Ltd.	Leicester.
Goodfellow, B., Ltd.	Hyde, near Manchester.
Grantham Crank and Iron Co., Ltd.	Grantham.
Greenwood & Batley, Ltd.	Albion Works, Leeds.

APPENDIX TO LECTURE III

Hall, J. P., & Co.	Oldham.
Hamblet, J.	Eagle Works, West Bromwich.
Hayes, Edward	Stony Stratford.
Heenan & Froude, Ltd.	Newton Heath, Manchester.
Hindley, E. S., & Sons	11, Queen Victoria Street, E.C.
Howden, J., & Co.	195, Scotland Street, Glasgow.
Isca Foundry and Engineering Co.	Newport, Mon.
Lees, T. & R.	Hollinwood, near Manchester.
Low Moor Co., Ltd.	Bradford.
Lytham Shipbuilding and Engineering Co.	Lytham, Lancashire.
Marshall, Sons & Co., Ltd.	Gainsborough.
McOnie, Harvey & Co., Ltd.	Scotland Street Engine Works, Glasgow.
Moreland, R., & Son	25 and 27, Old Street, E.C.
Napier Brothers, Ltd.	100, Hyde Park Street, Glasgow.
North-Eastern Marine Engineering Co., Ltd.	Wallsend-on-Tyne.
Perry, T., & Sons, Ltd.	Bilston, Staffordshire.
Plenty & Sons, Ltd.	Newbury, Berkshire.
Ransome, A., & Co., Ltd.	Chelsea, SW., and Newark.
Ransomes, Sims & Jefferies, Ltd.	Ipswich.
Reavell & Co., Ltd.	Ipswich.
Renshaw, W. R., & Co., Ltd.	Stoke-on-Trent.
Roger, R. & Co., Ltd.	Stockton-on-Tees.
Rose, Downs & Thompson, Ltd.	Old Foundry, Hull.
Ruston, Proctor & Co., Ltd.	Lincoln.
Russell, George, & Co., Ltd.	Motherwell, near Glasgow.
Scott Brothers	Halifax.
Scott & Mountain, Ltd.	Newcastle-on-Tyne.
Shanks, A., & Son, Ltd.	Bush Lane House, E.C.
Simpson, Strickland & Co., Ltd.	Dartmouth.
Smedley Brothers, Ltd.	Belper.
Smith, J., & Co.	Carshalton, Surrey.
Stewart, D., & Co., Ltd.	London Road, Glasgow.
Summerscales, W., & Sons, Ltd.	Keighley.
Taylor & Challen, Ltd.,	Birmingham.
Thornycroft, J. I. & Co.	Chiswick, W.
Tullis, D. & J. Ltd.	Clyde Bank, N.B.
Turner, E. R. & F., Ltd.	114, Ipswich.
Waddle Patent Fan and Engineering Co.	Llanelly
Walker Brothers	Pagefield Works, Wigan.
Willans & Robinson, Ltd.	Rugby.

Wootton Brothers	Coalville, near Leicester.
Yarrow & Co., Ltd.	Poplar, E.

SUPERHEATERS.

Anderton & Sons	Antley Boiler Works, Accrington.
Babcock & Wilcox, Ltd.	30, Farringdon Street, E.C.
Central Marine Engine Works	West Hartlepool.
Davey, Paxman & Co., Ltd.	Colchester.
Easton & Co., Ltd.	Broad Sanctuary Chambers, Westminster, S.W.
Fraser & Chalmers, Ltd.	43, Threadneedle Street, E.C.
Galloways, Limited.	Knott Mill Works, Manchester.
Hodgkinson, James	West High Street Works, Salford.
Mechan & Sons	Scotstoun Ironworks, Glasgow.
Rowland, B. R., & Co., Ltd.	Reddish, near Stockport.
Sinclair, George	Albion Boiler Works, Leith, N.B.
Simpson, J., & Co., Ltd.	Grosvenor Road, Pimlico, S.W.

TOOLS.

Allen, William	70, Port Street, Manchester.
Archdale, J., & Co	Birmingham.
Armstrong, Stevens & Son	Whittall Street, Birmingham.
Arrol, Sir W., & Co., Ltd.	Dalmarnock Ironworks, Glasgow.
Atlas Engineering Co.	Levenshulm, Manchester.
Batchelor, R. D.	Queen Victoria Street, E.C.
Berry, H., & Co., Ltd.	Croydon Works, Leeds.
Beyer, Peacock & Co., Ltd.	Gorton Foundry, Manchester.
Bolling & Lowe	2, Laurence Pountney Hill, E.C.
Bradbury & Co., Ltd.	Wellington Works, Oldham.
Britannia Co.	Colchester.
Buck & Hickman, Ltd.	2–4, Whitechapel Road, E.
Buckton, Joshua, & Co., Ltd.	Leeds.
Burton, Griffiths & Co.	Ludgate Square, E.C.
Butler, J., & Co.	Victoria Ironworks, Halifax.
Cameron, John, Ltd.	Salford, Manchester.
Campbells & Hunter, Ltd.	Dolphin Foundry, Leeds.
Chambers, Scott & Co.	Motherwell, Scotland.
Chatwin, T.	Great Tindal Street, Birmingham.
Clifton & Waddell	Johnstone, N.B.
Consoldiated Pneumatic Tool Co., Ltd.	Palace Chambers, Westminster, S.W.
Cunliffe & Croom, Ltd.	Broughton Ironworks, Manchester.
Daniell, A., Ltd.	Lion Works, Birmingham.

APPENDIX TO LECTURE III

Darling and Sellers, Ltd.	Keighley.
Davis & Primrose	Leith, N.B.
Dean, Smith & Grace, Ltd.	Keighley.
De Bergue & Co., Ltd.	Strangeways, Manchester.
Dempster, Moore & Co., Ltd.	49, Robertson Street, Glasgow.
Feather, W., & Co.	22, Gibraltar Road, Halifax.
Gibbins, R. C., & Co.	Berkley Street, Birmingham.
Greenwood & Batley, Ltd.	Albion Works, Leeds.
Guest, Keen & Nettlefolds, Ltd.	Birmingham.
Hadfield's Steel Foundry Co., Ltd.	Hecla Works, Sheffield.
Hardy Patent Pick Co., Ltd.	Sheffield.
Heap, Joshua, & Co., Ltd.	Ashton-under-Lyne.
Herbert, A., Ltd.	Coventry.
Hetherington, J., & Sons, Ltd.	Ancoats Works, Manchester.
Hill, Isaac, & Sons	St. George's Works, Derby.
Hulse & Co., Ltd.	Ordsal Works, Manchester.
Kendall & Gent	Bellevue Works, Manchester.
Lang, J., & Sons	Johnstone, near Glasgow.
Lee and Hunt	Arkwright Works, Nottingham
Loudon Brothers	39, West Campbell St., Glasgow.
Lowmoor Co., Ltd.	Bradford.
Midland Manufacturing Co., Ltd.	20 and 22, Change Alley, Sheffield.
Muir, W., & Co., Ltd.	Sherbourne Street, Manchester.
Musgrave Brothers	Crown Point Foundry, Leeds.
Noble & Lund, Ltd.	Felling, Newcastle-on-Tyne.
Parkinson, J., & Son	Canal Ironworks, Shipley, Yorks.
Phillips, J. W., & C. J.	23, College Hill, E.C.
Piercy & Co.	Broad Street Engine Works, Birmingham.
Pitt Machine Tool Co.	Liversedge, Yorkshire.
Rice & Co., Ltd.	Elland Road, Leeds.
Richards, G., & Co., Ltd.	Broadheath, near Manchester.
Richards, R., & Co..	Upper Ground Street, S.E.
Ryder, T., & Son	Turner Bridge Ironworks, Bolton, Lancashire.
Scott Brothers	Halifax.
Shanks, T., & Co.	Johnstone, Scotland.
Smart, J., & Co.	Erith, Kent.
Smith & Coventry, Ltd.	Gresley Works, Manchester.
Smith, G. F., Ltd..	Paragon Works, Halifax.
Smith, Hugh, & Co.	Possil Works, Glasgow.
Smith, T., & Sons of Saltley Ltd.	Saltley Mill, Birmingham.
Tangye Tool and Electric Co., Ltd.	Birmingham.
Taylor & Challen, Ltd.	Constitution Hill, Birmingham.

Turton, T., & Sons, Ltd.	Sheaf Works, Sheffield.
Ward, H. W., & Co.	Lionel Street, Birmingham.
Ward, T. W.	Saville Street, Sheffield.
Webster & Bennett	Coventry.
Wells, A. C., & Co.	102, Midland Road, St. Pancras, N.W.
Wicksteed, C., & Co.	Kettering.
Widdowson, J. H.	Ordsal Lane, Manchester.
Wilkinson, G., & Sons	Bradford Road, Keighley.
Wilkinson & Co.	Dudley.
Youngs,	Ryland St. Works, Birmingham.

Water Purification.

Babcock & Wilcox, Ltd.	30, Farringdon Street, E.C.
Baker's Patent Appliances Co., Ltd.	13, Huntriss Row, Scarborough.
Boby, William	Salisbury House, London Wall, E.C.
Doulton & Co., Ltd.	Lambeth, S.E.
Halliday, J., & Co.	James Street, Miles Platting, Manchester.
Harris Patent Feed-Water Filter, Ltd.	73, Queen Victoria Street, E.C.
International Purification Syndicate	5, Westminster Palace Gardens, London.
Lawrence Patent Water Softener Sterilizer Co., Ltd.	Norland Works, Uxbridge Road Station, W.
Mather & Platt, Ltd.	Salford Ironworks, Manchester.
Maxim, Sir Hiram, Electrical and Engineering Co., Ltd.	65, 66, 67, Gracechurch Street, E.C.
Pulsometer Engineering Co., Ltd.	Nine Elms Ironworks, Reading.
Renshaw, W. R., & Co., Ltd..	Stoke-on-Trent.
Thwaites Brothers, Ltd.	Bradford.
Wright, J., & Co.	Neptune Works, Tipton.

Valves, (Steam, Water, Gas, etc.).

Abbot, John, & Co., Ltd.	Park Works, Gateshead-on-Tyne.
Alley & MacLellan	Sentinel Works, Glasgow.
Auld, David, & Sons	Whitevale Foundry, Glasgow.
Bailey, W. H., & Co., Ltd..	Albion Works, Salford, Manchester.
Baker Blower Engineering Co.	Stanley Street, Sheffield.
Bell's Asbestos Co. Ltd.	59½, Southwark Street S.E.
Berry, Henry, & Co., Ltd.	Croydon Works, Leeds.

APPENDIX TO LECTURE III

Coltman, H., & Sons	Loughborough.
Daw, A. & Z.	11, Queen Victoria Street, E.C.
Donkin, B., & Clench, Ltd.	Lincoln Works, Chesterfield.
Empire Engineering Co.	Failsworth, Manchester.
Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Hanna, Donald & Wilson	Paisley, N.B.
Hayward-Tyler & Co.	91, Whitecross Street, E.C.
Holden & Brooke, Ltd.	Sirius Works, West Gorton, Manchester.
Hopkinson, J., & Co., Ltd.	Huddersfield.
Horseley Co., Ltd.	Tipton, Staffordshire.
Hunter & English	Bow, E.
Klinger, R., & Co.	66, Fenchurch Street, E.C.
Laidlaw, R., & Son, Ltd.	Glasgow.
Mather & Platt	Manchester.
Metallic Valve Co.	Tower Buildings, Water Street, Liverpool.
Musgrave Brothers	Leeds.
National Boilers and General Insurance Co., Ltd.	27, St. Ann's Square, Manchester.
Owens, S., & Co.	Whitefriars Street, E.C.
Piggott, Thomas, & Co., Ltd.	Birmingham.
Rice & Co., Ltd.	Elland Road, Leeds.
Rimington Brothers	Carlisle.
Royles Limited	Irlam, near Manchester.
Schäffer & Budenberg, Ltd.	Whitworth Street, London Road, Manchester.
Scotch and Irish Oxygen Co., Ltd.	Rosehill Works, Glasgow.
Scott, Ernest & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
Scott, George, & Son (London), Ltd.	44, Christian Street, E.
Simpson, J., & Co.	Pimlico, S.W.
Smith, Sydney, & Sons	Basford Brass Works, Nottingham.
Storey, I., & Sons, Ltd.	Empress Foundry, Manchester.
Tannett, Walker & Co.	Hunslet, Leeds.
Weir, G. & J., Ltd.	Cathcart, Glasgow.
Woodite Works.	Mitcham Common, Surrey.
Woods, H., & Co.	Salford, Manchester.

WATERWORKS PLANT, VALVES, HYDRANTS, FITTINGS, ETC.

Blakeborough, J., & Sons	Brighouse, Yorkshire.
Beck & Co.	130, Great Suffolk Street, Southwark, S.E.
Bird, F., & Co.	11, Great Castle Street, W.
Glenfield & Kennedy	Kilmarnock.

Guest & Chrimes	Rotherham.
Ham, Baker & Co.	13, Grosvenor Road, S.W.
Isler & Co.	Bear Lane, Southwark, S.E.
Stone, J., & Co.	Deptford.
Tylor, J., & Sons.	2, Newgate Street, E.C.
Waller, George, & Co.	165, Queen Victoria Street, E.C.
Warner, J., & Sons, Ltd.	Jewin Crescent, Cripplegate, E.C.

APPENDIX IV

LITERATURE

The following short list of Literature bearing on Municipal Engineering will prove of service to those seeking fuller information on the special subjects to which reference is made.

Building and Engineering Construction, Materials, etc.

Rivington's "Notes on Building Construction." Four volumes. (Longmans, Green & Co.)
"Instruction in Construction," by Colonel H. Wray, R.E. (Eyre & Spottiswoode.)
"Building Construction," by C. F. Mitchell. (B. T. Batsford.)
"Concrete, Its Use in Building," by T. Potter.
"Concrete, Its Nature and Uses," by George L. Sutcliffe.
"Foundations and Concrete Works," by E. Dobson.
"Builders' Work and the Building Trades," by Colonel H. C. Seddon.
"Science of Building," by E. W. Tarn.
"Engineering Construction in Iron, Steel and Timber," by W. H. Warren.
"Prevention of Dampness in Buildings," by A. W. Keim.
"Inspection of the Materials and Workmanship employed in Construction," by Austin T. Byrne.
Gwilt's "Encyclopædia of Architecture," by W. Papworth.
"Engineering Drawing," by W. Binns.
"Engineering Drawing and Design," by S. H. Wells.
"Dilapidations," by Professor Banister Fletcher.
"Valuations and Compensations," by Professor Banister Fletcher.
"Practical Treatise on Foundations," by W. H. Patton.
"Blasting and Quarrying of Stone," by General Sir J. Burgoyne.
"Stone, How to Get It, and How to Use It," by Major-General C. E. Luard.
"Treatise on the Strength of Materials," by Peter Barlow.
"Strength of Materials and Structures," by Sir J. Anderson.
"The Elasticity and Resistance of the Materials of Engineering," by W. H. Burr.
"The Materials of Construction," by J. B. Johnson.
"Strength of Materials," by M. Merriman.
"Strength of Materials, and Theory of Structures," by H. T. Bovey.

"Materials of Engineering," by R. H. Thurston. (3 Parts.)
"Testing of Materials of Construction," by W. C. Unwin.
"Handbook on Testing Materials," by A. Martens.
"Quantity Surveying," by J. Leaning.
"Quantities," by Professor Banister Fletcher.
"Quantities and Measurements," by A. C. Beaton.
"Shoring," by G. H. Blagrove.
"Shoring and Underpinning," by C. H. Stock and F. R. Farrow.
"Dangerous Structures," by G. H. Blagrove.
"Bridge and Tunnel Centres." (Spon.)
"Specification" (published annually).
"Building Specifications," by J. Leaning.
"Specifications in Detail," by F. W. Macey.
"Engineering Specifications," by Lewis M. Haupt.

CIVIL ENGINEERING, AND GENERAL.

"Civil Engineering," by Professor Rankine. (C. Griffin & Co.)
"Civil Engineering," by Law and Burnell. (Crosby, Lockwood.)
"Practical Tunneling," by F. W. Simms. (Crosby, Lockwood.)
Hurst's "Architects' Handbook of Formulæ, Tables and Memoranda."
"Architects' and Builders' Pocket Book," by F. E. Kidder.
"Engineers' Pocket Book," by Sir G. L. and H. B. Molesworth.
"Civil Engineers' Pocket Book," by John C. Trautwine.
"Mechanical Engineers' Pocket Book," by W. Kent.
"Useful Rules and Tables," by Professor Jamieson.
"Treatise on Civil Engineering," by D. H. Mahan.
"Bridge Construction," by T. Claxton Fidler, C.E. (C. Griffin & Co.)
"Proceedings of the Institution of Civil Engineers."
"The Sea Coast": Destruction, Littoral Drift, Protection, by W. H. Wheeler, C.E. (Longmans Green & Co.)
"Civil Engineering as applied to Construction," by L. F. Vernon-Harcourt, M.I.C.E. (Longmans Green & Co.)

ROAD ENGINEERING.

"Road Making and Maintenance," by Thomas Aitken, A.M.I.C.E. (C. Griffin & Co.)
"The Construction of Roads and Streets," by H. Law, and D. K. Clark. (Crosby, Lockwood.)
"Carriageways and Footways," by H. P. Boulnois, M.I.C.E. (Biggs & Co.)
"Construction of Roads, Paths, and Sea Defences," by F. Latham, C.E. (The Sanitary Publishing Co.)
"The Construction of Roads and Streets," by W. H. Maxwell, A.M.I.C.E. (The St. Bride's Press Ltd.)

APPENDIX IV

SANITARY AND MUNICIPAL ENGINEERING.

"Sanitary Engineering," by Colonel E. C. S. Moore, R.E. (B. T. Batsford.)
"Sewage Disposal Works," by W. Santo Crimp, M.I.C.E. (C. Griffin & Co.)
"Purification of Sewage and Water," by W. J. Dibdin, F.I.C. (The Sanitary Publishing Co.)
"Recent Improvements in Bacterial Treatment by Sewage," by W. J. Dibdin, F.I.C. (The Sanitary Publishing Co.)
"Sewage, and the Bacterial Purification of Sewage," by Samuel Rideal, D.Sc. London. (Robert Ingram.)
"Sewerage and Sewage Disposal," by Professor H. Robinson, C.E. (Spon.)
"Sewage Treatment and Utilization," by W. H. Corfield, M.D. (Macmillan & Co.)
"Sewage Purification," by E. Bailey-Denton, C.E. (E. & F. N. Spon.)
"Sewerage and Sewage Disposal of a Small Town," by E. B. Savage, A.M.I.C.E. (Biggs & Co.)
"Municipal and Sanitary Engineers' Handbook," by H. P. Boulnois, M.I.C.E. (Spon.)
"Sewer Construction," by W. H. Maxwell, A.M.I.C.E. (Hodgetts, Ltd.)
"Drainage of Lands and Towns," by G. D. Dempsey (revised by D. K. Clark). (Crosby, Lockwood.)
Adam's "Local Government Board Requirements for Bacterial Sewage Dispoal Works.
Thudichum's "Bacterial Treatment of Sewage."
"Drainage Work," by W. H. Maxwell, A.M.I.C.E. (St. Bride's Press.)
"House Drainage Manual," by W. Spinks, A.M.I.C.E. (Biggs & Co.)
"Practical Sanitation," by George Read, M.D. (C. Griffin.)
"Practical Sanitary Science, by W. H. Maxwell, A.M.I.C.E. (Parts I. and II.) (The Sanitary Publishing Co.)
"Disposal of Towns' Refuse," by W. F. Goodrich. (P. S. King & Son.)
"Town Refuse Destructors," by W. H. Maxwell, A.M.I.C.E. (The Sanitary Publishing Co.)
"Refuse Disposal and Power Production," by W. Francis Goodrich, A.I.Mech.E. (Archibald Constable & Co.)
"Destructors and Steam Production," by W. H. Maxwell, A.M.I.C.E. (R. E. Institute, Chatham); see also "Destructors," in *Encyclopædia Britannica*, vol. xxvii.
"Proceedings of the Association of Municipal and County Engineers." (T. Cole, Secretary.)
"Journal of the Sanitary Institute."

"MELDRUM"

DESTRUCTORS

- - - ARE WORKING AT - - -

Electricity Works

- Ayr
- Bangor
- Burnley
- Canterbury
- Christchurch, N.Z.
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